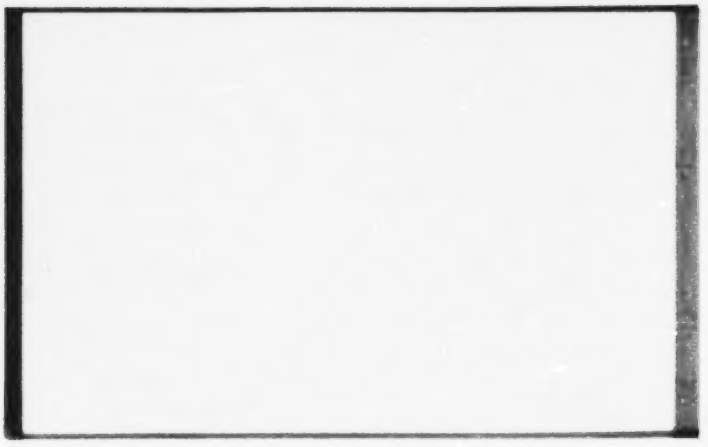
BC
B685E59
D:R473
1982
c.3



ENERGY USE SERVICES

The Energy Use Engineering Department provides engineering, technical and marketing impact advice on energy use with emphasis on energy management, prudent energy usage, efficient applications and energy conservation.

The service is provided by a team of four sections supervised as follows:

*HEATING, AIR CONDITIONING, VENTILATION & REFRIGERATION	Dr. Z. El-Ramly, P.Eng.	(663-3277)
*ELECTRICAL & LIGHTING (including associated wiring, electronics, and codes)	R.F. Hughes, P.Eng.	(663-3280)
*RESIDENTIAL APPLICATIONS (including associated appliances, lighting, wiring, water heating, electric and gas vehicles, solar, small hydro, wind, wood, and biomass)	J.E. Elliott, P.Eng.	(663-3285)
*APPLICATIONS ENGINEERING (primarily commercial and industrial — including associated total-energy district and waste water applications; electric and gas vehicles, and power factor and demand control)	M.W. Bodnar, P.Eng.	(663-3288)

Please don't hesitate to contact us should you require additional information or should you have any suggestions on how we can better provide the service required.

R.W. RACINE, P.ENG.
MANAGER, ENERGY USE ENGINEERING DEPARTMENT
(604)663-3268 (TELEX 0454395)

ENERGY USE ENGINEERING DEPARTMENT
ENERGY CONSERVATION DIVISION
B.C. HYDRO AND POWER AUTHORITY

625 HOWE STREET
VANCOUVER, B.C.
V6C 2T6

PROJECT 7812

RESIDENTIAL HEAT PUMP'S

POTENTIAL CONTRIBUTION

TO ENERGY NEEDS IN B. C. 1980-2005

SYNOPSIS:

If anticipated technological improvements are achieved, heat pumps will be expected to reduce the average residential electric space heating accounts by 171 kW.h/year and the average residential electric account by 42 kW.h/year by year 2005. Total savings on the Hydro system would be 60 GW.h/year. The corresponding figures for Vancouver Island are 233 kW.h/year, 108 kW.h/year and 33 GW.h/year. All these figures are based on probable forecast, optimistic forecasts are even higher (103 GW.h/year for overall Hydro system).

PROJECT:

Initiated/Requested by:	T. J. Newton, P.Eng.
Date Completed:	July 1982
Completed by:	Dr. Z. El-Ramly, P.Eng./ H. M. Lau, P.Eng
Supervised by:	Dr. Z. El-Ramly, P.Eng.
Coordinated by:	D. G. Henrigues, P.Eng.
Approved by:	R. W. Racine, P.Eng., Manager Energy Use Engineering
Initial Distribution:	T. J. Newton EUE Supervisors

JR38.2

Canadian Cataloguing in Publication Data

Main entry under title:
Residential heat pump's potential impact to energy needs in B.C., 1980-2005

Includes bibliographical references.
"Project 7812"
ISBN 0-7719-9038-3

1. Heat pumps - British Columbia. 2. Dwellings - British Columbia - Energy consumption. I. B.C. Hydro. Energy Use Engineering Dept.

TH7638.H42 697 C82-092266-8

7812

D76-459

ENERGY USE ENGINEERING DEPARTMENT

PROJECT SUMMARY

PROJECT No. 7812 PRIORITY 3

TITLE: RESIDENTIAL HEAT PUMP'S POTENTIAL CONTRIBUTION TO ENERGY NEEDS IN B.C. 1980 - 2005

INITIATED/REQUESTED BY: T.J. Newton

ASSIGNED TO: R.T. Martin ASSIGNED BY: R.W. Racine

DATE ASSIGNED: 1 February 1978 DATE REQUIRED: by 1 June 1978

ESTIMATED COMPLETION: May 1978 COMPLETED: 15 July 1982

OBJECTIVES AND NOTES:

Planning and implementing activities for meeting and alleviating conventional electric, gas and oil energy needs requires utilization and impact data on:

(a) current practical solutions
(b) potential alternative solutions

for the B.C. situations involved.

Heat pumps (all types) can be an element contributing to the desired solutions. Provide an updated report covering:

1. (a) and (b) above in general.
2. Per unit characteristics summary for the situation involved, e.g., a 1200 sq. ft. house, insulated as recommended (refer 'C' in H308 and 309).
3. Example applications and impacts on Vancouver Island for the 1980 - 2005 25 year period.

Coordinate with others involved. Provide a pessimistic, probable and optimistic range of possibilities where appropriate. Refer DG 223 and 506.

The primary objective is to develop an updated summary based on available information by 1 June 1978 with the idea that the report can be updated later if required.

COPIES TO: DEPARTMENT MANAGER (THEN RECORD FILE), BLUE FILE, SUPERVISOR, EUE Supervisors and staff involved

T.J. Newton

R. Schneider

PLEASE ADVISE AS SOON AS POSSIBLE IF CHANGES ARE REQUIRED ABOVE

TABLE OF CONTENTS

		Page
	SUMMARY	i
1.	INTRODUCTION	1
	1.1 What is a Heat Pump?	1
	1.2 Types of Heat Pumps	2
	1.3 How Could the Heat Pump Contribute to Energy Conservation?	3
2.	CURRENT PERFORMANCE OF HEAT PUMPS	4
3.	ANTICIPATED FUTURE PERFORMANCE OF HEAT PUMPS	5
4.	FACTORS AFFECTING HEAT PUMP'S ENERGY CONSERVATION POTENTIAL	7
	4.1 Weatherization and Lifecycle Changes	7
	4.2 Regions and Climate	7
	4.3 Solar Energy and Internal Heat Gains	7
5.	FACTORS AFFECTING THE WIDESPREAD USE OF HEAT PUMPS - SATURATION	9
	5.1 Economics	9
	5.1.1 Favourable Financing	10
	5.1.2 Tax Incentives	10
	5.1.3 Federal Government Canadian Oil Substitution Program (COSP)	10
	5.1.4 Gas and Electric Rates Structures	10
	5.2 Regulatory Base	11
	5.3 Promotional Base	11
6.	METHODOLOGY AND RESULTS	12
	6.1 Anticipated Future Heat Pump SPF	12
	6.2 Penetration - Saturation of Heat Pump	12
	6.3 Method of Analysis	14
	6.4 Typical Results	14
	6.5 Overall Results and Discussion	17
	6.6 Effect on B. C. Hydro System	19
7.	CONCLUSION	21
8.	REFERENCES	22

APPENDICES

APPENDIX A - A Practical Method for Energy Conservation Impact Analysis

APPENDIX B - Heat Pump Data Sheets EC 1800 and EC 1810

APPENDIX C - Heat Pump Operating Cycle

APPENDIX D - Preliminary Data Sheet H 309, Relative Energy Consumptions and Costs for Residential Space Heating

APPENDIX E - Flow Chart of Heat Pump Energy Savings Forecast Computer Program

APPENDIX F - Forecast Tables to Year 2005

SUMMARY

This report examines the potential impact of heat pumps on energy needs for B. C. to year 2005. The study uses best available data and anticipated technological improvements, together with B. C. Hydro's forecasts for growth in number of accounts, augmented by Statistics Canada population growth forecast, to predict energy savings in electric space heating accounts as a result of increased use of heat pumps.

Future electric space heating requirements which consider impact of energy conservation and weatherization are obtained from Project 7857. Project 7857, in turn, allows for existing and future housing stock by year of construction, dwelling type and insulation levels.

The penetration of heat pumps for space heating in homes is dependent on the different geographic climatic conditions in the province. Due to this sensitivity, the study is conducted and presented for the six* Hydro regions and the total system.

The method used in this study is outlined in Appendix A, A Practical Method for Energy Conservation Impact Analysis.

Table I summarizes the main results for the overall Hydro system.

Figures I, II, III and IV show the trend and are graphical representations of Table I.

Figure V shows the impact of heat pumps superimposed on the probable impact of weatherization for the average space heating consumption.

* The main findings of the study were completed before the amalgamation of Metro and Fraser Valley divisions into Lower Mainland Division.

Base year 1980*:

Average energy use per residential electrical account = 8,871 kW.h/yr
Average energy use per electric space heating account = 16,835 kW.h/yr
Average space heating usage per electric space heating account = 7,500 kW.h/yr

Forecast Year	1985			1995			2005		
Forecast	Pes	Prob	Opt	Pes	Prob	Opt	Pes	Prob	Opt
Per Heat Pump Htg Account** kW.h/yr	3,375	3,456	3,496	2,973	3,142	3,321	2,865	2,983	3,194
% ***	45	46	47	40	42	44	38	40	43
Per Residential Htg Account** kW.h/yr	6	13	28	41	74	128	77	171	294
% ***	0.08	0.17	0.37	0.55	0.99	1.71	1.03	2.28	3.92
Per Residential Elec Account** kW.h/yr	1	2	5	9	16	27	19	42	72
% ***	0.01	0.03	0.07	0.12	0.21	0.36	0.25	0.56	0.96
Total Reduction GW.h/yr	1.0	2.1	4.7	11.3	20.7	35.6	26.9	59.9	102.8

TABLE I: Annual Saving in Electric Heating Consumption

* Data from Project 7857.
** This represents the saving in average annual consumption per account based on B. C. Hydro forecast to 1990. Between 1990 and 2005, Statistics Canada population growth trends are used to extrapolate Hydro's 1990 forecast and the impact of weatherization. For more details refer to Project 7857.
*** This represents the saving as a percentage of 1980 average electric space heating usage.

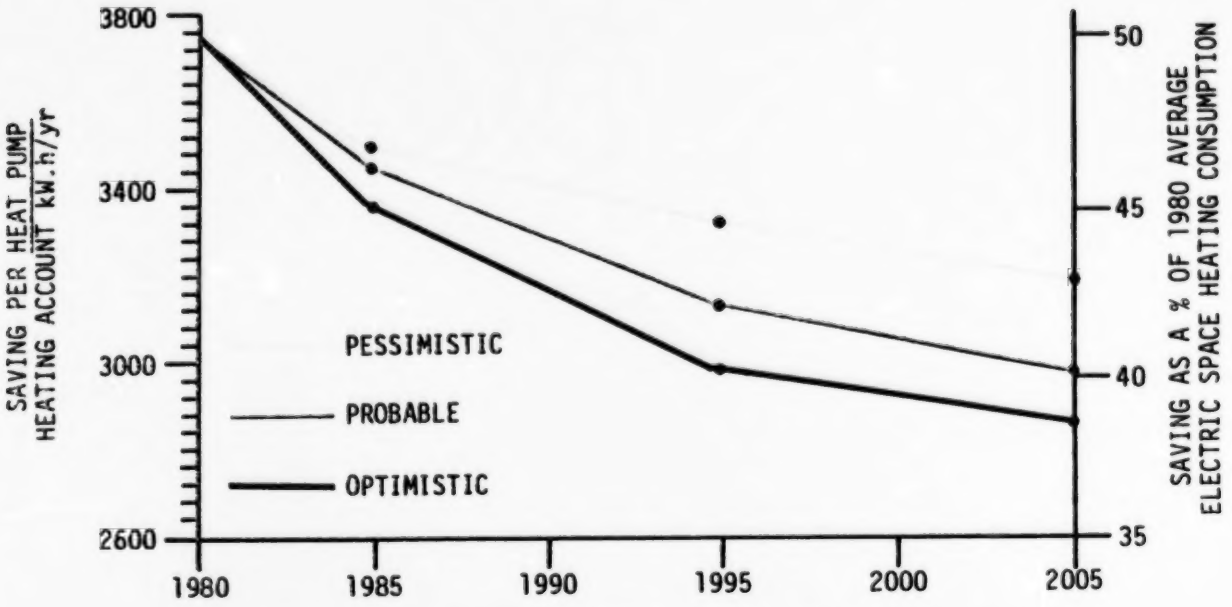


FIGURE I: ANNUAL SAVINGS IN ELECTRIC HEATING CONSUMPTION PER HEAT PUMP HEATING ACCOUNT: 1980-2005 kW.h/yr

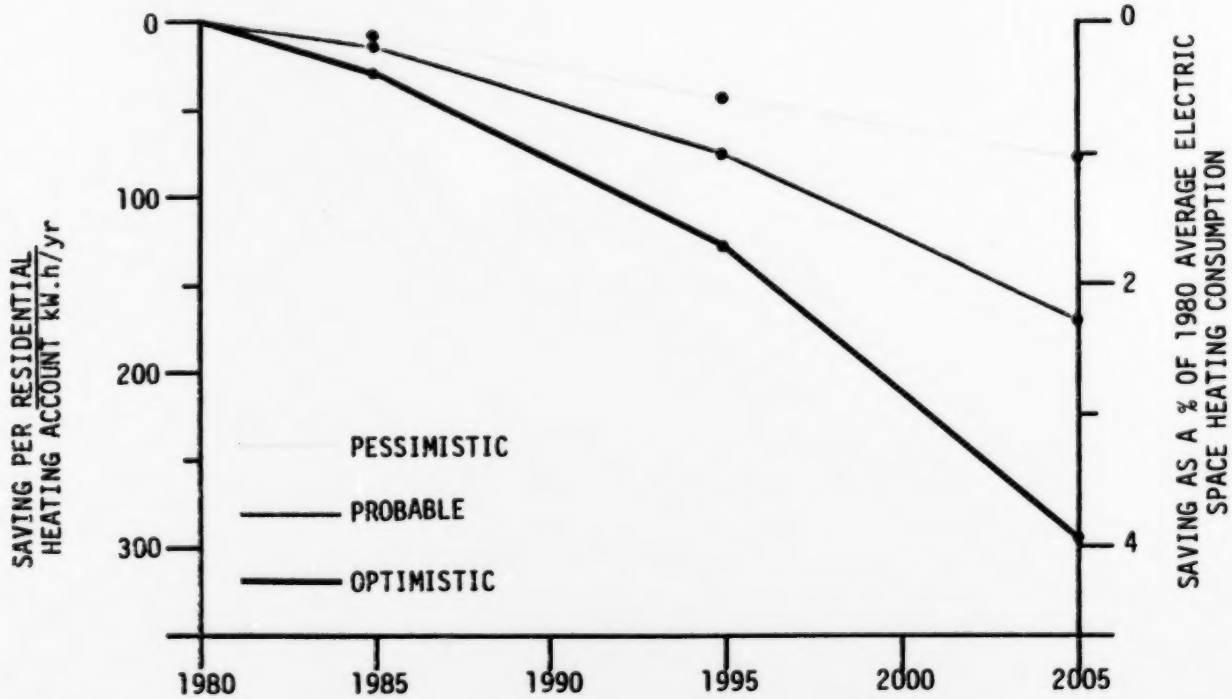


FIGURE II: ANNUAL SAVINGS IN ELECTRIC HEATING CONSUMPTION PER RESIDENTIAL HEATING ACCOUNT: 1980-2005 kW.h/yr

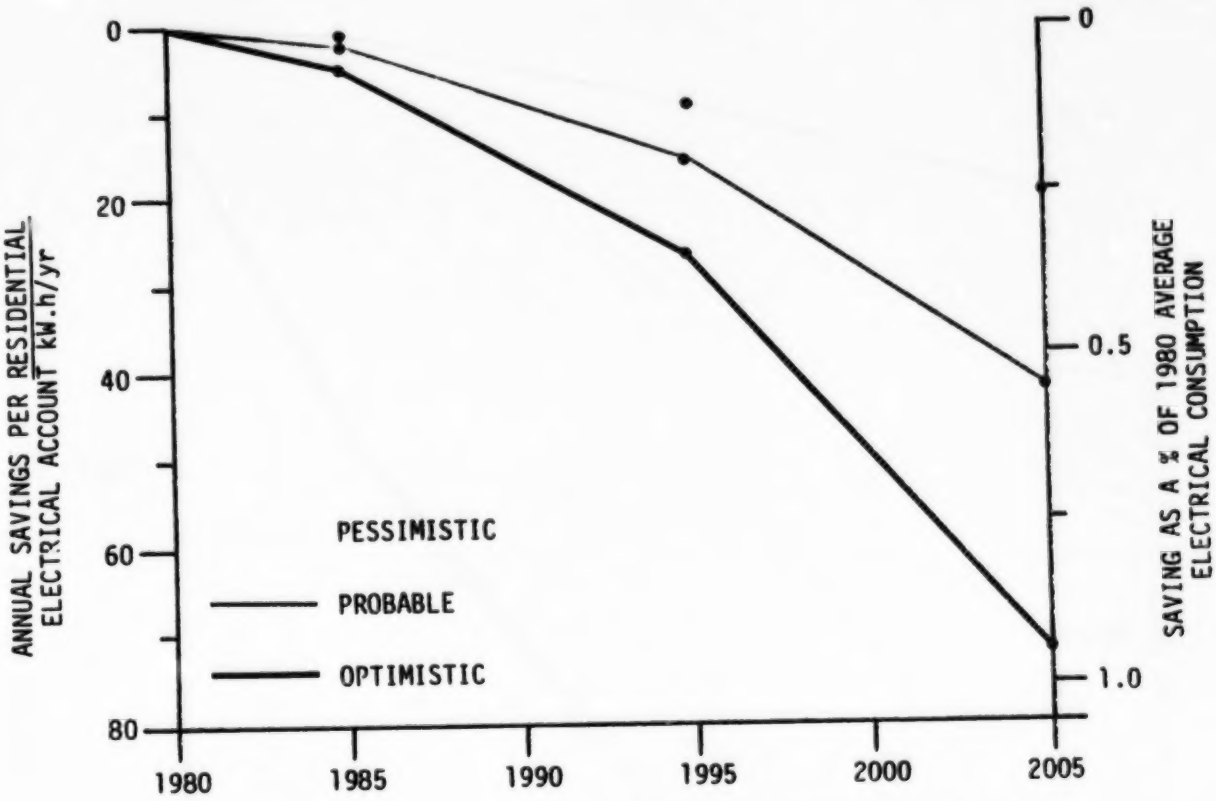


FIGURE III: ANNUAL SAVINGS IN ELECTRIC HEATING CONSUMPTION PER RESIDENTIAL ACCOUNT: 1980-2005 kW.h/yr

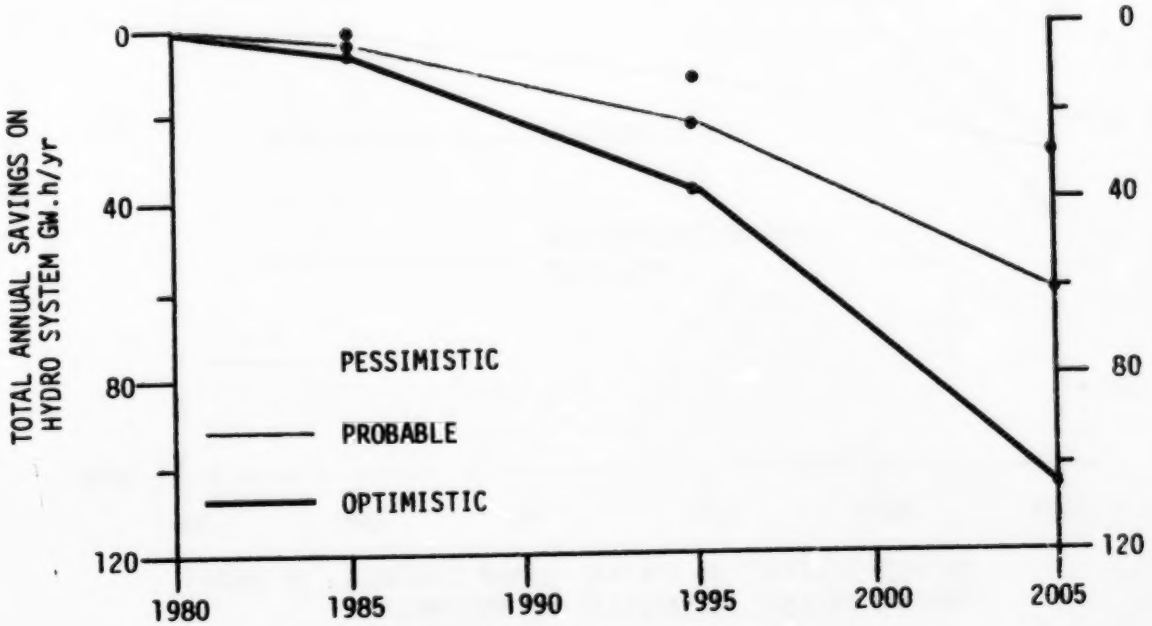


FIGURE IV: TOTAL ANNUAL SAVINGS IN ELECTRIC HEATING CONSUMPTION ON HYDRO SYSTEM: 1980-2005 GW.h/yr

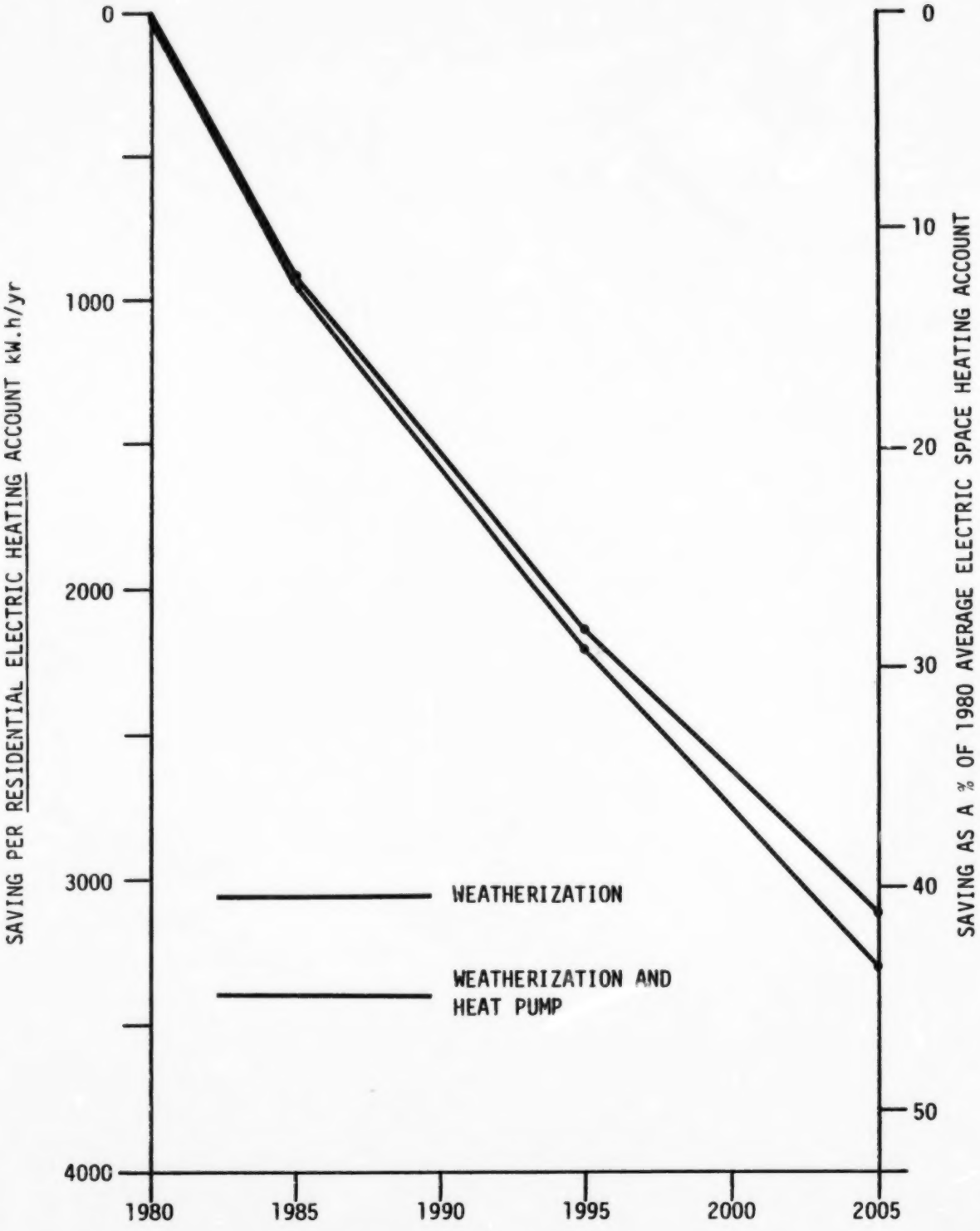


FIGURE V: PROBABLE ANNUAL SAVINGS IN ELECTRIC HEATING CONSUMPTION PER RESIDENTIAL HEATING ACCOUNT: 1980-2005 kW.h/yr

1. INTRODUCTION

This report is a first attempt at investigating the impact of a certain energy conserving device, namely the heat pump, on future energy needs for B. C. to year 2005. The study uses B. C. Hydro's forecasts of future growth in number of accounts supplemented by Statistics Canada and BCEC forecasts together with best available information to calculate that impact. This study is conducted in such a way as to facilitate updating whenever more refined data or parameters are available and to allow for interaction with other studies.

Although heat pumps as heating devices have been on the market for many years, they have not had wide application. Not only were the earlier models poorly designed for cold weather operation, but they could not compete economically with conventional heating systems. In the last few years, however, with improved models and greatly increased prices of fuel and electricity, renewed interest has developed.

1.1 What is a Heat Pump?

A heat pump is a device consisting of a compressor, a refrigerant fluid and two heat exchangers. It is capable of moving heat into or out of a building depending on the direction of flow of the refrigerant fluid. As illustrated in Figure 1, the device is usually made in two parts, an outdoor unit and an indoor unit.

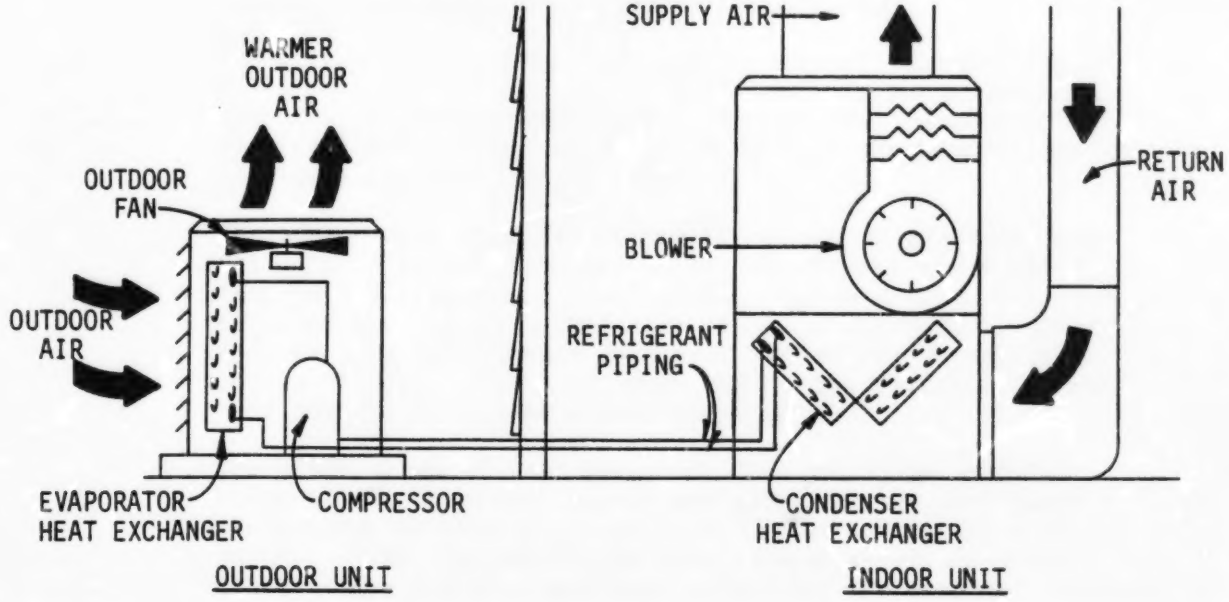


Figure 1: Heat Pump Operation Heating Mode

Most heat pumps in use are air-to-air heat pumps designed to provide cool air in the summer and warm air in the winter. In summer, heat extracted from the inside air is pumped to the outside. In winter, heat is extracted from the outside air and pumped inside the building. The principle of operation is the same as the common household refrigerator.

The operational characteristics of a heat pump for heating are unfortunately not as one would desire. The useful heat that can be extracted, decreases with decrease in outside temperature. The heating requirement of the building on the other hand, increases with decreasing outside temperature. Consequently, heat pumps need to be supplemented by another heating system to increase their heat output when the outdoor air temperature is below the "balance point" (the temperature below which the heat pump cannot meet the heating requirement). Usually electric resistance heaters would be turned on to provide the supplementary heat for the house.

1.2 Types of Heat Pumps

Heat pumps for residential space heating service are generally unitary type. The equipment is either a self contained packaged (factory assembled) unit or a split system unit where the indoor and outdoor sections are connected together during installation via refrigeration piping at the site. Heat pumps are classified according to the type of heat source and sink. Data Sheets E 1800 and E 1810 (Appendix B) will provide more detailed information on heat pump operations, systems and applications. The following is a brief description of the types of heat pumps being used in the province.

The air-to-air electric heat pump is the most common type in B. C. The ambient air acts as both the heat source and sink. When the outdoor air temperature is below the "balance point", electric resistance heaters would turn on to provide the supplementary heat for the house.

The add-on heat pump is essentially an air-to-air heat pump designed to be added to gas or oil fired warm air furnaces (Appendix B, see Data Sheet E 1810). The heat pump is turned off when the outdoor temperature is below the "balance point" and the warm air furnace is turned on to provide the main source of heat. Energy is saved during the operation of the heat pump in the milder winter temperature.

The other types of heat pumps are the gas fired assisted, solar assisted, ground source and water source heat pumps. Their usage in this province is still limited and on a trial basis. They operate in the same manner as an air-to-air conventional electric heat pump except for the external source of heat.

The gas fired assisted heat pump has gas burners in the outdoor unit to provide the supplementary heat. It extracts the heat from the gas flame and also from the condensing flue gases. In this mode of operation, it is similar to a condensing gas furnace. The solar assisted heat pump relies on the heat from the solar panels. The ground and water source heat pumps gain heat from the ground and water respectively. The water may come from a stream, lake, sea or ground.

1.3 How Could the Heat Pump Contribute to Energy Conservation?

Heat pumps not only convert electric energy to heat, they also use electric energy to move heat from the outside of the house to the inside (or vise versa in summer). Since the process is not strictly energy conversion, the term efficiency is not used. Instead, performance of heat pump is measured by the ratio of the heat delivered to the work done (energy used); this ratio is called the coefficient of performance, COP.

A heat pump with a high COP will have a higher potential for energy conservation in that more heat is being delivered to the building than the energy used by the system. For example, a heat pump with a COP of 2, would deliver twice as much heating energy as it would consume in electrical energy to drive the compressor.

The ideal thermodynamic heat pump cycle (Appendix C) is the reversible Carnot cycle which has a COP of around 20. This would present a tremendous opportunity in saving energy. However, the Rankine refrigeration cycle is more representative of a practical heat pump cycle. It has a theoretical COP of around 5.

The actual COP is much lower and is in the 1.1 to 3.5 range. This is due to the inefficiencies of the various components in the heat pump system. The major factors which affect the COP of a heat pump are:

- the heat and refrigerant losses in the sliding port reversing valve which is used to reverse the operation of the heat pump from heating to cooling or vice versa;
- the compressor mechanical inefficiency;
- the defrost cycle in defrosting the outdoor coil during low outdoor air temperature;
- inefficient electric motors;
- high pressure drop in the heat exchangers;
- and finally the slow response of the expansion valve for the wide range of operating conditions.

2. CURRENT PERFORMANCE OF HEAT PUMPS

Performance of heat pumps over the whole heating season is measured by the "Seasonal Performance Factor - SPF". SPF is defined as the total heating output divided by the total electrical requirements. Electric input includes the input requirements to the compressor, fans and auxiliary resistance heaters for the entire heating season.

Performance of current generation of heat pumps can be represented by the following equation (Reference 1):

$$SPF = 2.7 - 0.00016 \times (\text{Degree Days in } °F).$$

For Lower Mainland and Vancouver Island the SPF attainable today is around 1.9. For Central Interior it is as low as 1.3.

3. ANTICIPATED FUTURE PERFORMANCE OF HEAT PUMPS

Heat pumps have been traditionally designed and marketed as economical cooling equipment which can provide heating service upon reversal of its operating cycle for warm climatic regions. They do not perform as well here where the winter heating load far exceeds the summer cooling load. Among the many problems experienced are low seasonal performance factor and high maintenance requirements.

In order to succeed as a space heating equipment, a northern climate heat pump must be designed with heating service as its main function. Reference 2 has shown that significant improvement in efficiency and reliability can be achieved by making design changes based on the use of existing heat pump components as listed below.

The existing sliding port reversing valve can be redesigned to eliminate the heat and mass leakage between the hot and cold sides of the heat pump. This improvement alone could result in a 5-10% increase in the heat pump COP.

The heating mode COP can be increased by another 10% if a high efficiency compressor is used. Moving the compressor and controls to an indoor location would reduce shell and piping losses, eliminate the need of crankcase heating and ease in the maintenance.

A demand defrost system and proper orientation of the outdoor coil would increase the COP by 8%.

A 10% COP improvement could result if energy efficient motor and fan combinations are used for both the indoor and outdoor unit.

The provision of a suction accumulator heat exchanger could increase the transient response of the heat pump, following a defrost cycle or being turned on. Together with an oil return heat exchanger, there is a potential heat pump COP improvement of 2%.

A further 2-4% impovement in COP can be achieved by an electric expansion valve to maintain an optimal refrigerant flow in the receiver over a wide range of winter operating conditions.

The improvement in COP from each of these design changes are not necessarily additive since some of these features may reduce the effect of others.

Some newer models of heat pumps are equipped with two speed compressor staged to match the varying heating and cooling load during the year. The compressor operates on low speed under moderate heating or cooling loads and automatically shifts to high speed under heavy loads. The two speed compressor would minimize operating energy consumption and increase the seasonal performance factor.

Reference 3 reported on the development of an advanced electric residential heat pump which would be 20% more efficient than existing heat pumps with the use of a dual stroke (capacity) compressor. However, this is still in the research stage.

The duplex Stirling heating-only gas-fired heat pump, Reference 4, is another possibility in the technical improvement on the performance of heat pumps.

These development and design changes to existing heat pumps for heating service with significant improvement and reliability in our climatic conditions are not revolutionary. They can be achieved (reference 2) and with the right market conditions (see Section 5), a new generation of northern climate heat pumps will come into service for space heating in homes.

4. FACTORS AFFECTING HEAT PUMP'S ENERGY CONSERVATION POTENTIAL

Electric heat pumps have the potential of reducing the annual electric space heating consumption substantially. With SPF of 2, homes heated with heat pump systems can reduce by up to 50% the energy consumed by electric resistance heaters. The potential impact of heat pumps on the electric energy consumption of homes depends on the interactive effects of weatherization (how well the house is insulated), maintained space temperatures, regional or climatic conditions, solar energy and other sources of internal heat gain.

4.1 Weatherization and Lifestyle Changes

The impact of weatherization and energy conservation measures (lifestyle changes) such as lower thermostat settings and night setback on future electric space heating requirements are dealt with in Project 7857. These measures are relatively simple and cost effective to implement. As their impact increases, the future electric space heating requirements per customer account would decline. This in turn would reduce the potential impact of electric heat pumps to reduce the annual electric heating consumption.

4.2 Regions and Climate

The Lower Mainland, Vancouver Island and North Coast regions have a mild coastal climate. With the exception of a few cold winter periods, the average daily ambient temperature is above the "balance point" of heat pumps. This climate is favourable for the use of heat pump space heating systems.

In the Southern Interior region where summer cooling is desirable, heat pump space heating and cooling systems are gaining acceptance.

Due to the severity of the winter climate in the Central Interior region, the potential impact of electric space heating heat pump system is somewhat limited.

Owing to the sensitivity of geographic climatic conditions and the effect of weatherization, this study is conducted for each of the six Hydro regions and the total system.

4.3 Solar Energy and Internal Heat Gains

Heating energy is required to maintain the space temperature inside the house when the rate of heat loss from the house envelope exceeds the rate of heat generated by solar energy, people, lights and appliances. If the house is heated using a solar heating system, supplementary heat is required during cloudy or cold winter days and nighttime.

The use of efficient lighting systems and appliances would reduce the internal heat gains. This increases the heating energy requirement.

The effects of solar energy and other sources of internal heat gains on energy consumption for space heating using electric heat pumps are not considered in this study. Project 7926 will make a first attempt at considering all these factors and their interactive effects.

5. FACTORS AFFECTING THE WIDESPREAD USE OF HEAT PUMPS - SATURATION

The energy management and conservation potential of heat pumps in residential applications have been known to exist for some years. Their popularity as space heating systems in both existing and new homes are influenced by the economics (life cycle costs) of the system in comparison to conventional heating systems. Financial incentives and energy costs provide the indirect means of changing the economics. Regulations and/or an informed public are the direct ways to increase saturation.

5.1 Economics

Historically, heating systems in houses were selected based on first costs alone. With rising energy prices, homeowners are becoming aware of the operating cost of their heating systems. A true economic analysis should consider, besides initial cost and energy consumption, the cost of maintenance, interest charges (debt financing), government grants and system replacement costs. An evaluation of the various heating systems has to consider all these costs over the system life. This procedure is known as the life cycle cost analysis.

Energy Use Engineering Department has a computer program which calculates the life cycle cost of the various heating systems such as the gas/oil/electric forced air furnaces, electric baseboard/ceiling cable and electric heat pump. Data Sheet H 309 (see Appendix D, Relative Energy Consumptions and Costs for Residential Space Heating) presents the results of this computer program.

The electric heat pump annual energy consumption and costs are the lowest of all the other heating systems in all regions. However, the installation of a heat pump space heating system has an initial cost of $3,000 to $4,000 more than a conventional gas furnace warm air heating system. The life cycle cost analysis (Appendix D) shows that in regions where natural gas service is available (Vancouver Island has butane-air gas service), the gas furnace heating system is the cheapest system to own and operate.

At present heat pump residential heating systems are not competitive with gas furnace systems due to their higher initial capital cost. New home builders are also reluctant to install heat pumps as they would increase the capital cost of houses being built. The heat pump system is viable when the house is electrically heated and summer cooling is desired, thus the higher initial cost is shared between the cooling and heating functions of the heat pump.

In future, with rapidly rising energy costs and the anticipated technological improvement in heat pumps, the life cycle cost will improve and would be comparable to the gas furnace heating system.

From the energy conservation viewpoint, heat pump should be the residential heating system to use especially for poorly insulated existing houses where there is a greater potential to reduce the space heating energy requirement. However, financial incentives are required to encourage the use of heat pumps. These incentives can be comprised of the following.

5.1.1 Favourable Financing

Low or zero interest rate loans or grants provided by governments or utilities towards the additional costs of heat pumps would encourage their widespread use.

5.1.2 Tax Incentives

Sales tax exemption and capital cost depreciation of heat pumps applied to home owners or landlords income as tax reductions.

5.1.3 Federal Government Canadian Oil Substitution Program (COSP)

The COSP provides a grant for home owners to replace oil which is used for space heating. In British Columbia the electric heat pump is eligible for this financial incentive except in diesel generation areas. On Vancouver Island, it would have to be an add-on electric heat pump/oil furnace heating system to qualify for a COSP grant. This is a viable alternative to the installation of an all electric heating system since the existing 100 amp electrical service can be used with the add-on electric heat pump in most households. This combination heating system will have the advantage of the efficient operation of the heat pump during most of the heating season and the use of the oil furnace as backup to be used only in the extreme cold weather.

The add-on electric heat pump/gas furnace heating system would also be attractive to a homeowner who is retrofitting his house and desires cooling during the summer months. Again, the initial cost of the heat pump is higher than a conventional cooling unit, but the operation of the heat pump would save energy and money during the heating season.

5.1.4 Gas and Electric Rates Structures

Higher rates in general and higher trailing rates in particular, would encourage the use of the more efficient heat pump heating systems as their life cycle cost becomes comparable to that of the gas furnace warm air heating system.

5.2 Regulatory Base

If the government introduces legislation governing the amount of energy use (energy budget) for home heating and the efficiency of the heating equipment, heat pumps would probably be the only type of equipment which can be used for home heating and comply with the energy budget regulation, . However, it may be very difficult to accomplish and enforce or even agree on the level of the energy budget.

An informed and educated public, rather than regulation, will probably increase the demand for heat pumps . As part of this communication process, regulations could be introduced, demanding minimum efficiency or rating on all home heating equipment and this information publicized as in the Energuide Program.

5.3 Promotional Base

The public in general, is not fully aware of the energy conservation potential of heat pumps. There is no strong leadership in the use of heat pump technology which is relatively new compared to the conventional oil and gas heating furnaces. A promotional and advertising campaign consisting of technical literature, newspaper, radio and TV advertising would make the public aware of the pros and cons of heat pumps in the different climatic regions in B. C. An informed and educated public, together with financial incentives, would encourage the widespread use of heat pumps.

With the rapid escalation of fuel costs and the introduction of the Canada Oil Substitution Program (COSP), there is an increase in market activity by heat pump manufacturers especially in areas where there is no natural gas service. The market for heat pumps would increase if the financial incentives and promotional base campaign are implemented. They, in turn, would provide the incentive for the manufacturers to develop, manufacture and market a Canadian northern climate heat pump which is designed principally for space heating and improve its seasonal performance factor, machine reliability and reduce its maintenance requirements. With improved performance, the life cycle cost of heat pumps would be comparable to conventional heating systems. Thus, their usage would increase.

6. METHODOLOGY AND RESULTS

6.1 Anticipated Future Heat Pump SPF

Having identified the factors which will affect the anticipated technological improvement for heat pumps (Section 3), our engineering judgement and experience were used to project the pessimistic, probable and optimistic improvement on the seasonal performance factor of heat pumps to year 2005. Table 1 shows these projections for each region.

6.2 Penetration - Saturation of Heat Pump

As discussed before, an important factor in heat pump acceptance as a heating system is its life cycle cost. As heat pumps become more efficient (higher SPF), they will be more cost effective. Hence, their market penetration will increase in future years.

The highest potential for heat pumps is in the Southern Interior; basically it is due to the need/desirability of summer air conditioning. Consequently, their impact is significant in this region. In Vancouver Island, because of the favourable climatic conditions, the COSP grant for off-oil conversion in existing homes and the absence of natural gas, heat pump penetration is expected to be relatively high too.

In the coastal regions of Metro, Fraser Valley and North Coast, the market penetration of heat pumps will not be as significant. This is due to the availability of natural gas service, higher initial cost of heat pumps and less requirement of summer air conditioning.

The impact of the electric heat pump is expected to be limited in the Central Interior Region. The severity of its winters results in less effective operation of the heat pump and more significant use of auxilliary heat below the balance point. Thus, the potential energy conservation of the heat pump during the heating season is limited.

Table 1 shows that the heat pumps SPF would improve by 1985. This in turn would increase the market penetration of heat pumps for space heating expecially in the Southern Interior and Vancouver Island regions.

HEAT PUMP SPF AND MARKET PENETRATION

	Year		Metro	FrVal	CentI	NorCo	SoInt	VanIs
		Total Cons/Hts Acct,*	14046	17676	19762	20959	17222	16879
	1980	Lighting & Appliances,**	4775	4775	4775	4775	4775	4775
		Allow for Hot Water,**	4580	4580	4580	4580	4580	4580
P	1985	S.P.F., ***	2	2	1.6	2	1.9	2
E		Penetr, ****	0	0	0	0	0.5	0.25
S	1990	S.P.F.,	2	2	1.6	2	2	2
S		Penetr,	0.25	0.25	0	0.25	1	0.5
I	1995	S.P.F.,	2.1	2.1	1.7	2.1	2.0	2.1
M		Penetr,	1	1	0.5	1	2.5	1.5
I	2005	S.P.F.,	2.3	2.3	1.9	2.3	2.2	2.3
S		Penetr,	2	2	0.75	2	5	3
	1985	S.P.F.,	2	2	1.6	2	2	2
P		Penetr,	0	0	0	0	1	0.5
R	1990	S.P.F.,	2.1	2.1	1.7	2.1	2.1	2.1
O		Penetr,	0.5	0.5	0.25	0.5	2	1.9
B	1995	S.P.F.,	2.2	2.2	1.8	2.2	2.2	2.2
A		Penetr,	1.5	1.5	0.5	1.5	4	3
B	2005	S.P.F.,	2.4	2.4	2.0	2.4	2.3	2.4
L		Penetr,	3	3	1	3	10	8
E	1985	S.P.F.,	2.1	2.1	1.7	2.1	2.0	2.1
		Penetr,	0.25	0.25	0	0.25	2.0	1.0
O	1990	S.P.F.,	2.2	2.2	1.8	2.2	2.1	2.2
P		Penetr,	0.75	0.75	0.5	0.75	3	2.0
T	1995	S.P.F.,	2.4	2.4	2.0	2.4	2.3	2.4
I		Penetr,	2.5	2.5	0.75	2.5	6	5
M	2005	S.P.F.,	2.7	2.7	2.3	2.7	2.5	2.7
I		Penetr,	5	5	1.5	5	15.0	13.0
S								
T								
I								
C								

* Data from B. C. Hydro Projection of Gross Load Requirements 1980/81:1990/91.

** Data from Project 7857.

*** Anticipated SPF for heat pump.

**** Percentage of penetration of electric heat pump with respect to the total number of electric space heating accounts.

TABLE 1

6.3 Method of Analysis

A computer program (see Appendix E for flow chart) was developed to predict the electric energy savings due to the use of heat pumps in each region and the total Hydro system. It utilized the data from Project 7857.

In each forecast type (pessismistic, probable and optimistic) for each forecast year in each region, the program will gather the data from Project 7857 data file on:

(a) the number of heating and residential accounts to year 2005;

(b) 1980 base year average electric heating account consumption; and

(c) probable savings due to weatherization and other space heating energy conservation measures.

Together with the projected heat pump SPF and market penetrations (Table 1), the program calculates the annual savings in electrical energy per heating account and per residential account. The total savings for each region and the overall Hydro system are also calculated to year 2005.

6.4 Typical Results

Table 2 shows a sample probable forecast in energy savings due to the impact of heat pumps for the forecast years 1995 and 2005. In the table, the current (forecast year) heating consumption is computed by the computer program using the 1980 base year average electric heating account consumption less the energy consumption by lighting and appliances (L&A), domestic hot water (HW) and energy savings due to weatherization. (Data from Project 7857.)

ENERGY SAVINGS WITH INCREASED USE OF HEAT PUMPS

PROBABLE - 1995

REGION	# OF ACCOUNTS FORECAST		1980 CONSUMPTION PER ELEC HTG ACC			FORECAST SPACE HTG	SPF	Z PENET.	SAVINGS IN kWhr/yr TOTAL	PER ACC HTG	RES
	HTG (a)	RESID. (b)	TOTAL (c)	L&A. (d)	H.W (e)	(f)	(g)	(h)	(i)	(j)	(k)
Metro	65000	472700	14046	4775	4580	3290	2.2	1.50	1749740	27	4
Fraser Valley	32000	255800	17676	4775	4580	6457	2.2	1.50	1690520	53	7
Central Interior	21000	119800	19762	4775	4580	7884	1.8	0.50	367939	18	3
North Coast	10000	36900	20959	4775	4580	10040	2.2	1.50	821436	82	22
Southern Interior	38000	156500	17222	4775	4580	6811	2.2	4.00	5646610	149	36
Vanc. Island	112000	277300	16879	4775	4580	5689	2.2	3.00	10426800	93	38
ALL HYDRO	278000	1319000							20703100	74	16

PROBABLE - 2005

REGION	# OF ACCOUNTS FORECAST		1980 CONSUMPTION PER ELEC HTG ACC			FORECAST SPACE HTG	SPF	Z PENET.	SAVINGS IN kWhr/yr TOTAL	PER ACC HTG	RES
	HTG	RESID.	TOTAL	L&A.	H.W						
Metro	80000	514300	14046	4775	4580	2821	2.4	3.00	3948760	49	8
Fraser Valley	43000	278300	17676	4775	4580	5800	2.4	3.00	4364640	102	16
Central Interior	29000	130300	19762	4775	4580	6444	2.0	1.00	934371	32	7
North Coast	13000	40100	20959	4775	4580	8915	2.4	3.00	2028270	156	51
Southern Interior	45000	170200	17222	4775	4580	6264	2.3	10.00	15932700	354	94
Vanc. Island	140000	301800	16879	4775	4580	4998	2.4	8.00	32650700	233	108
ALL HYDRO	350000	1435000							59859500	171	42

TABLE 2: Typical Regional Results

JR38.2

The total energy savings in each region is equal to the current (forecast year) energy consumption less the heat pump energy consumption multiplied by the percentage of penetration in the residential space heating accounts.

For example, in the Metro region - forecast year 1995:

(a) Current (1995) space heating

$$= f$$

$$= \underline{3,290} \text{ kW.h/yr}$$

(b) Energy savings per heat pump space heating account

$$= f - \frac{f}{g}$$

$$= 3,290 - \frac{3,290}{2.2}$$

$$= \underline{1,795} \text{ kW.h/yr}$$

(c) Total energy savings, i = (f-(f/g)) x (h/100) x (a)

$$= (3,290 - (3,290 \div 2.2)) \times (1.50 \div 100) \times 65,000$$

$$= \underline{1,749,740} \text{ kW.h/yr}$$

(d) Energy savings per heating account, j

$$= \frac{\text{Total Energy Savings (i)}}{\text{Number of Electric Space Heating Accounts (a)}}$$

$$= \frac{1,749,740 \text{ kW.h/yr}}{65,000}$$

$$= \underline{27} \text{ kW.h/yr}$$

(e) Energy savings per residential account, k

$$= \frac{\text{Total Energy Savings (i)}}{\text{Number of Electrical Residential Accounts (b)}}$$

$$= \frac{1,749,740 \text{ kW.h/yr}}{472,700}$$

$$= \underline{4} \text{ kW.h/yr}$$

The total energy savings for the overall Hydro system is the total for the energy savings in the six regions.

The remaining tables for all other forecast years and type of forecast are listed in Appendix F.

6.5 Overall Results and Discussion

The energy savings results are consolidated in the Annual Reduction Per Heating Account (kW.h/yr), Table 3 and the Annual Reduction Per Residential Account (kW.h/yr), Table 4.

ENERGY SAVINGS FORECAST WITH INCREASED USE OF HEAT PUMPS

ANNUAL REDUCTION PER HEATING ACCOUNT kWhr/year

Region / Forecast Year	1985			1990			1995			2005		
	Pes.	Prob	Opt.	Pes.	Prob	Opt.	Pes.	Prob	Opt.	Pes.	Prob	Opt.
Metro	0	0	5	4	9	15	17	27	48	32	49	89
Fraser Valley	0	0	10	9	18	29	34	53	94	66	102	183
Central Interior	0	0	0	0	9	20	16	18	30	23	32	55
North Coast	0	0	15	13	28	44	53	82	146	101	156	281
Southern Interior	18	38	75	36	75	113	85	149	231	171	354	564
Vanc. Island	8	16	34	15	60	66	45	93	166	85	233	409
All Hydro	6	13	28	14	41	52	41	74	128	77	171	294

TABLE 3

ENERGY SAVINGS FORECAST WITH INCREASED USE OF HEAT PUMPS

ANNUAL REDUCTION PER RESIDENTIAL ACCOUNT kWhr/year

Region / Forecast Year	1985			1990			1995			2005		
	Pes.	Prob	Opt.	Pes.	Prob	Opt.	Pes.	Prob	Opt.	Pes.	Prob	Opt.
Metro	0	0	0	1	1	2	2	4	7	5	8	14
Fraser Valley	0	0	1	1	2	3	4	7	12	10	16	28
Central Interior	0	0	0	0	1	3	3	3	5	5	7	12
North Coast	0	0	4	3	7	11	14	22	40	33	51	91
Southern Interior	4	8	15	8	16	24	21	36	56	45	94	149
Vanc. Island	3	5	11	5	21	34	18	38	67	39	108	190
All Hydro	1	2	5	3	8	10	9	16	27	19	42	72

TABLE 4

The annual saving in electric heating energy consumption based on the type of account and as a percentage of the 1980 average electric space heating usage are listed in Table 5. The table also shows the total reduction in electric energy needs due to the use of heat pumps for the Hydro system.

Tables 3, 4 and 5 show that the real potential of heat pumps is not expected to materialize until after the year 1985.

With more efficient heat pumps (higher SPF) and a large number of installations, the impact is expected to increase. However, this is moderated by the impact of weatherization which would reduce the space heating energy consumption requirements. This reduces the potential impact of the heat pump by reducing the probable annual savings per heat pump account of 3,456 kW.h/yr or 46% of 1980 electric space heating usage in forecast year 1995 to 2,983 kW.h/yr or 40% in year 2005.

6.6 Effect on B. C. Hydro System

The overall effect on Hydro electric system would be a probable reduction in electric energy consumption of 2.1 GW.h/hr in 1985 to 59.9 GW.h/yr by 2005. These savings in electric energy are achieved during periods when the outdoor temperature is mild and above the heat pump "balance point". During extreme cold periods, the all electric heat pump system would have to turn on the electric resistance supplementary heaters to heat the house. This would increase the peak load to near that of the straight resistance heating system. As a result, the Hydro electric system will experience a reduction in load factor with little reduction impact on demand load.

The add-on heat pump would be a more attractive alternative to the Hydro electric system in that during extreme cold weather it is switched to fossil fuel such as oil for the main source of heat. There is no increase in electric peak load and the load factor may improve since the add-on heat pump would have a base load even during the summer months. However, if the fossil fuel is natural gas, it will also create a load factor problem to Hydro gas system.

A study has been proposed (Project 8107) for comprehensive field testing of heat pumps in the different climatic regions of B. C. Their owning and operating costs, maintenance problems, energy savings potential and impact on the Hydro system would be assessed.

Base year 1980*:

Average energy use per residential electrical account = 8,871 kW.h/yr
Average energy use per electric space heating account = 16,835 kW.h/yr
Average space heating usage per electric space heating account = 7,500 kW.h/yr

Forecast Year	1985			1995			2005		
Forecast	Pes	Prob	Opt	Pes	Prob	Opt	Pes	Prob	Opt
Per Heat Pump Htg Account** kW.h/yr	3,375	3,456	3,496	2,973	3,142	3,321	2,865	2,983	3,194
% ***	45	46	47	40	42	44	38	40	43
Per Residential Htg Account** kW.h/yr	6	13	28	41	74	128	77	171	294
% ***	0.08	0.17	0.37	0.55	0.99	1.71	1.03	2.28	3.92
Per Residential Elec Account** kW.h/yr	1	2	5	9	16	27	19	42	72
% ***	0.01	0.03	0.07	0.12	0.21	0.36	0.25	0.56	0.96
Total Reduction GW.h/yr	1.0	2.1	4.7	11.3	20.7	35.6	26.9	59.9	102.8

TABLE 5: Annual Saving in Electric Heating Consumption

* Data from Project 7857.
** This represents the saving in average annual consumption per account based on B. C. Hydro forecast to 1990, between 1990 and 2005 statistics. Canada population growth trends are used to extrapolate Hydro's 1990 forecast and the impact of weatherization. For more details refer to Project 7857.
*** This represents the saving as a percentage of 1980 average electric space heating usage.

7. CONCLUSION

This report is prepared as a first attempt to evaluate the potential impact of heat pumps on the electric energy consumption of homes to year 2005. Its impact is dependent on the interactive effects of weatherization, lower space temperature, night setback, solar energy, lighting, appliances and domestic hot water usage.

The electric heat pump has energy management and conservation potential in residential space heating applications. Their widespread use will depend on their future improved performance and reliability and implementation of financial incentive programs. By 2005, the pessimistic, probable and optimistic energy savings for the total Hydro electric system are 26.9 GW.h/yr, 59.9 GW.h/yr and 102.8 GW./yr respectively.

8. REFERENCES

1. "Unitary Air-To-Air Heat Pumps" by J. E. Christian, ICES. Integrated Community Energy Systems, Oak Ridge National Laboratory report - ANL/CES/TE 77-10, July 1977.

2. "Optimization and Evaluation of a Northern Climate Residential Air Source Heat Pump" by Ontario Hydro Research Division. Canadian Electrical Association Contract # 76-12 report, October 1980.

3. "Advanced Electric Residential Heat Pumps" by S. E. Vega, Westinghouse Electric Corporation. Oak Ridge National Laboratory Subcontract # 86X-24712 report, 1981.

4. "Duplex Stirling Heating - Only - Gas Fired Heat Pump Feasibility Study" by W. T. Beale, C. F. Rankin, D. Gedeon, C. Kingelman, Sunpower Inc. Gas Research Institute Report # GRI 79/0047.

APPENDICES

Appendix A

A PRACTICAL METHOD FOR ENERGY CONSERVATION IMPACT ANALYSIS

A PRACTICAL METHOD FOR ENERGY CONSERVATION IMPACT ANALYSES

INTRODUCTION

THE NEED

There is need for good estimates of the potential impact of various energy conservation alternatives. Such information is required for forecasting, planning, budgeting, setting priorities and selecting the most beneficial actions.

IDEAL IMPACT ANALYSES

Accurate impact analyses require reliable details on the number, type, capacity, usage characteristic and developments underway for each application and equipment involved throughout the province. Although much of this is available for many applications, such as heating, water heating and processes, much more needs to be continually surveyed and tabulated for ideal analyses.

Ideal analyses will be costly to obtain and will not be possible for a long time - in fact they may never be available because of the details involved.

A PRACTICAL METHOD

The next approach in developing practical impact analyses is to:

- Use the reliable information available in the B. C. Hydro PRODUCT SALES ANALYSIS on energy use-per-account for the customer groupings in both gas and electric services.

- Apportion the use-per-account to the major usages, such as for heating, lighting, motors, processes, etc., based on analyses of typical situations and experience.

- Give weightings to the various energy conservation actions possible in each main application of consequences, based on the present day average use-per-account for each major usage, expert information of the highly probable technical improvements within the next 25 years and judgment by the various specialists involved of the range of potential saturation resulting from the various major energy conservation actions.

The following charts summarize this approach, which we have developed as a practical method for energy conservation impact analyses.

INTERPRETATION OF DATA

The impact band varying from pessimistic to optimistic has value in indicating the range of impacts we can expect. The three values extracted from this range can be interpreted to mean:

Pessimistic, P

What we can expect with a continuation of past practice, with only a token energy conservation effort.

Probable, P

The most probable impact taking into account the changes we can expect with an increasing concern for energy conservation practices.

Optimistic, O

The best we can expect short of rationing and strict regulation.

FUTURE USAGE

Note that the potential energy conservation impacts are related to the present day (1980) per-account usage base. Should this information be applied to forecasting total future usage, allowances will be required for probable increased usage for:

- Increased conveniences, recreation and food production and productivity aids.
- Environmental amelioration.
- New applications such as electric and gas vehicles, industrial processes and off-peak heat-storage.

Energy conservation actions will have beneficial impact in also minimizing these additional usage needs.

SUMMARY

The approach herein should initiate a practical basis for systematically analyzing the potential impact of energy conservation alternatives, which can be periodically refined and updated as pertinent new information becomes available.

The approach herein provides the following key features:

1. Impacts are related to records of actual current usage in each application (e.g. the total savings are a percent of the current usage in each application).

Future impact updatings can similarly provide practical data by relating to future current records available on a monthly and annual basis for each region.

2. Impacts are coordinated to B. C. Hydro forecasts of future growth in number of accounts.

3. Impacts are coordinated to avoid misleading accumulations. For example, savings from solar and heat pump systems in future years relate to future better insulated buildings and savings in air conditioning relate to lower lighting watts/m^2 in the future.

4. Impact evaluation of each energy conservation alternative in each major electric and gas application in the B. C. Hydro service area is provided.

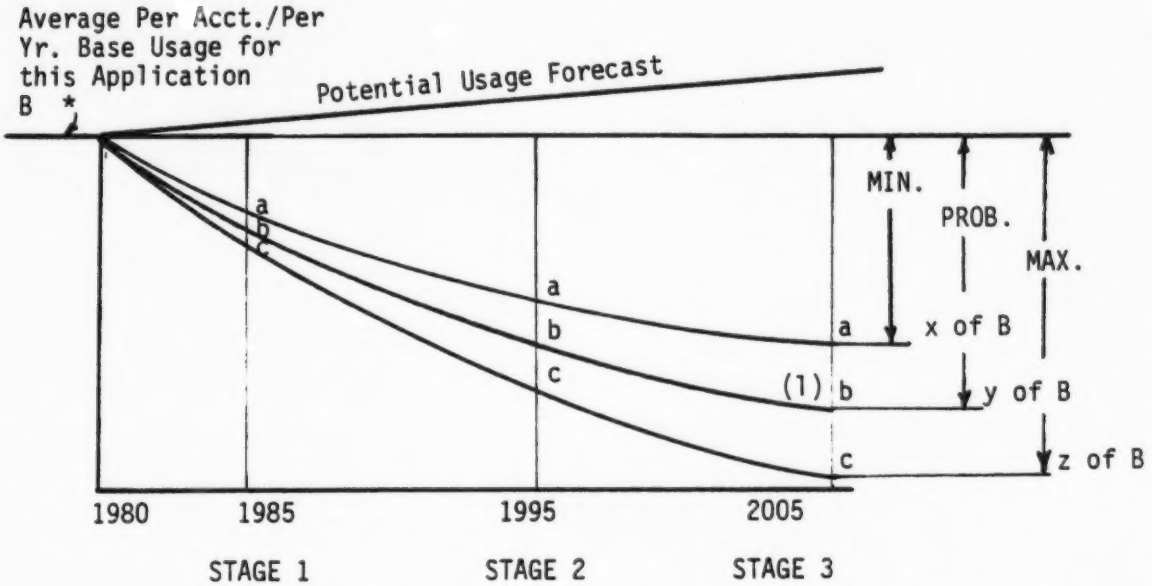
5. Impact evaluation of elements such as new developments, more efficient practices, retrofit, standards and marketing activity is provided.

6. B. C. Hydro electric and gas system totals are provided - impacts by region could be developed if required.

7. A systemized basis which can be adapted to also cover impacts on peak demands, revenues, capitalization and customer costs; impacts of new loads and impacts in each region is provided.

Because of the importance of sound impact evaluations to B. C. Hydro operations, plans are to extend and refine the impact analyses initiated herein to periodically provide updated information as required. Comments and suggestions will be appreciated.

A PRACTICAL METHOD OF ENERGY CONSERVATION IMPACT ANALYSIS



* For existing accounts B = average from billings
For new accounts B = present average for new additions in 1979/1980

METHOD

1. Identify the minimum, probable and maximum improvements possible with technical practicability in each application and account grouping by 1985, 1995 or 2005 as appropriate depending on the latest information available.

2. Apply potential minimum, probable, maximum impact on saturation for each EC action - for existing and new installations to locate points 1a, b, c; 2a, b c; 3a, b, c.

3. Apply the resultant reductions to the number of accounts to obtain pessimistic, probable and optimistic impacts for each application and account grouping to develop averages per account per year energy conservation impact curves corresponding to a, b, c above.

FIGURE 1A

	*A Sales in 10^8 BU	1980 BCH Comm & Ind *B Space Htg Nat. Gas Consumption % of Total Sales
1980 BCH Commercial & Industrial Total Natural Gas Sales	5.39	54
1980 BCH Overall Total Natural Gas Sales	8.58	34

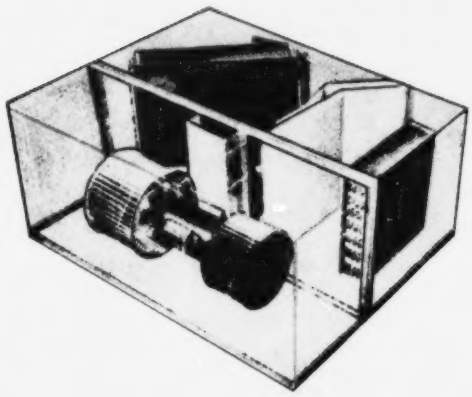
*A BU = Billing Units.
*B 1980 BCH Com. & Ind. Space Htg Nat. Gas Sales = 2.93×10^8 BU.

79/5/22:RWR
ENERGY USE ENGINEERING DEPT.

ENERGY CONSERVATION DIVISION
B.C. HYDRO

APPENDIX B

HEAT PUMP DATA SHEETS
EC 1800 and EC 1810



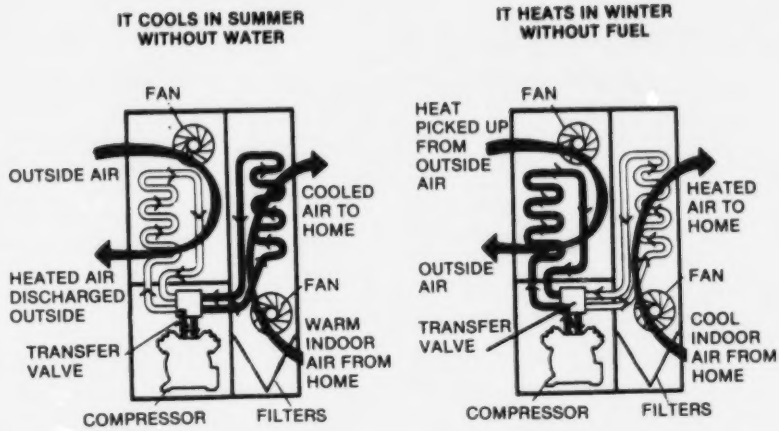


Figure 1

INTRODUCTION

With the concern today for conserving energy, the heat pump is being re-examined as a possible solution to the problem. The heat pump is a device which makes use of the heat in the outdoor air or in lake, river or well water to heat a building in the winter. It achieves this by using the same principles as the domestic refrigerator which extracts heat from the food and rejects it to the room air. If you check the rear of your refrigerator, you will feel the heat being given off — heat that was taken from the stored produce.

The heat pump takes heat from the outdoor air and pumps it into the building when heat is required. It also removes heat from the building and rejects it to outdoors for summer cooling. In essence it is a refrigerative air conditioner with a special valve to allow reversing the refrigerant flow. (See Figure 1)

THE IDEAL CYCLE

The two energy-gas cycles used to evaluate the heat pump are the Carnot and Rankine. The Carnot cycle is considered ideal and represents the highest possible performance, however the Rankine cycle, which assumes irreversible expansion at constant enthalpy through a throttling valve is generally more indicative of the vapour compression cycle.

The ideal Carnot cycle is assumed to have temperature limits of 21 °C condensing and 7 °C evaporating which would result in a Coefficient of Performance (COP) of 21.2. The losses due to:

— temperature gradients across all transfer surfaces

— fan power to provide forced air movement over transfer surfaces

— pressure drop through piping, valves, etc.

— compressor being not 100% efficient

— losses due to defrosting coils

all bring the ideal COP down to a value of about 3.0 for a typical unitary air-to-air heat pump.

COEFFICIENT OF PERFORMANCE

The heat pump is rated by how much power it uses relative to how much heat it gives off — or its Coefficient of Performance.

$$COP = \frac{\text{kW heat output}}{\text{kW electricity input}}$$

A typical heat pump, using outdoor air as the heat source, will have a COP of about 3.0 in mild weather and only 1.5 when it is -12 °C outdoors. This means that the energy available is directly related to the outdoor air temperatures which unfortunately is opposite to what we require — we need more heat in winter and less in mild weather. It is also why the heat pump is fitted with duct heaters, or strip heaters as they are sometimes called, to provide extra resistance heating in very cold weather.

SEASONAL PERFORMANCE FACTOR

The Seasonal Performance Factor (SPF) represents a heat pumps average seasonal operating efficiency.

$$SPF = \frac{\text{Total useful output (heat \&/or cooling)}}{\text{Total Energy Input}}$$

The total energy input during the heating season includes the portion of heating supplied by direct resistance heaters that are normally necessary to supplement the heat available from the heat pump.

PERFORMANCE STANDARDS

CSA Performance Standard C 273.3 can be used to provide the customer with some assurance that the heat pump will perform its function quietly, efficiently, with a capacity as rated, and suitable for a wide range of outdoor temperatures.

Other existing standards applicable to the heat pump include UL559-1964 by Underwriters Laboratory and ARI240-67 by the Air Conditioning & Refrigeration Institute.

TYPES OF UNITS

The air-to-air heat pump is the one usually found in operation in B.C. Other heat sources can be used, but their use is usually limited to commercial applications. For example, the Oakridge shopping centre in Vancouver had a heat pump installation using well water. Care has to be taken with these applications that the water source is adequate in temperature and flow, as the heat pump can freeze the source by extracting heat faster than it can be replaced.

SIZING

The heat pump should be sized on its cooling capacity. This means the building's cooling, or air conditioning requirements dictate the size of the unit to be selected.

In residential applications the cooling load is usually such that additional heating capacity has to be added. In commercial applications — especially where there are large internal heat gains from lights, machinery and people, the heat pump may have sufficient heating capacity for year round operation.

INSTALLATION

The cost of installation of heat pumps is a little more than the cost of an air conditioning unit only, and about the same as a heating and air conditioning package. This means that the $4,000.00 — $5,000.00 cost for a residential application is high relative to a conventional heating system. The price is reasonable for commercial applications and this is the area where the heat pump should be seriously considered.

DUCT HEATERS

To ensure adequate heating capacity for winter operation, duct heaters are installed in conjunction with the heat pump. These heaters are normally sized for 100% of the heating requirements which provides a safety feature in the event of machinery failure during the winter.

OTHER APPLICATIONS

The principle of the heat pump can be applied to other areas.

Heat Transfer — this is useful from an energy conservation viewpoint. In many commercial buildings, some areas require cooling all year round — such as interior zones in an office building. This heat is often rejected directly outdoors even when other areas require heating at the same time. A heat pump can transfer the heat, cooling the interior zone and heating the perimeter area, saving both heating and cooling energy.

Even dual-duct systems can be economical to operate if the heat pump principle is used. If the cooling coil is the evaporator coil and the heating coil is the condenser coil, then the heat pump can transfer heat from each duct. Extra heat or extra cooling can be obtained using an outdoor coil which can boost the evaporator coil in summer and the condenser coil in winter. (See Figure 2) This principle can be applied in a number of ways; to preheat or precool outdoor air, to heat perimeter zones while cooling interior zones, to pick up heat from water to sewer, to heat domestic water, etc.

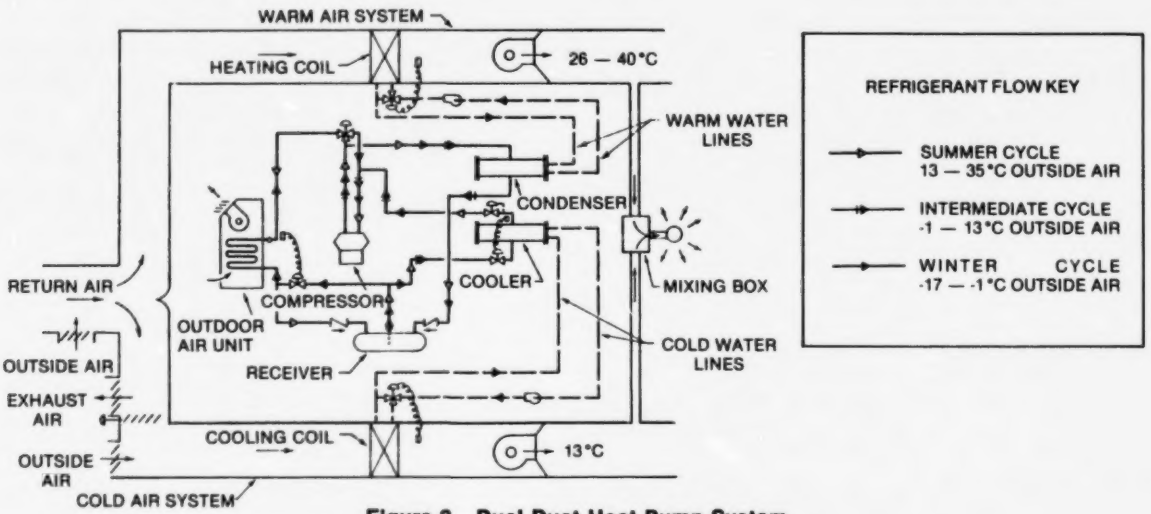


Figure 2 Dual Duct Heat Pump System

Another method is what is known as the "California Heat Pump" concept. This uses a water pipe loop around all floors. Heat can be removed or added to the water in the loop by an individual heat pump in various areas around the structure. (See Figure 3) This allows the areas heated by the sun to be cooled, their heat added to the water and cold areas heated by taking the heat out of the pipe. In extremely hot weather, a cooling tower is used to reject all heat outdoors and in cold weather, a boiler adds heat to the water.

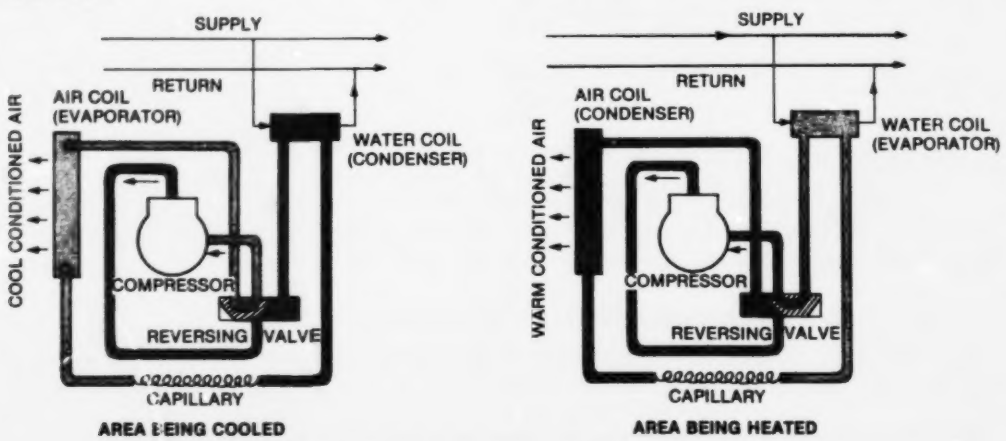


Figure 3 Heat Transfer System

This type of system is very suitable for multizone buildings such as offices, hotels, apartments, hospitals, etc., where individual zone control is required and heating and cooling loads can occur in various areas at the same time.

HEAT RECOVERY

In some industries, large amounts of heat are rejected in ventilation air, and water to drain. Often this heat can be recovered to preheat or temper make-up air or preheat water. There are many devices that can be used for this purpose, such as heat wheels, heat pipes and run around coils in addition to the heat pump. Each of these pieces of equipment has its own place and application and a consulting engineer experienced in this field should be retained for these applications.

SUMMARY

The heat pump is an efficient method of using low grade heat sources to provide heating of a structure plus providing summer cooling. It is not economical for residential applications at the present time but with price increases in fuel oil and natural gas, this could change if electricity costs do not increase at similar rates.

The heat pump is a good choice for heating and cooling of commercial buildings. Specialized applications of the unit can be used in a variety of structures such as offices, stores, hospitals, hotels, apartments and schools.

The air-to-air unit is the practical choice for small buildings and residential applications. Water-to-air units are more suitable to larger buildings and heat transfer systems.

INSTALLATIONS

The information shown herein is a guideline only. B.C. Hydro is not responsible for installations. Installations are the responsibility of the installer and should meet the current requirements of the owner, manufacturer's instructions and all applicable regulations.

ADVISORY SERVICES FOR HOME AND INDUSTRY

Helpful information for the trades and Hydro customers is available from the local B.C. Hydro office or the Energy Use Engineering department, 970 Burrard Street, Vancouver, B.C. V6Z 1Y3.

replaces E 1800A/AC 215
1979 AUGUST: RGC
energy use engineering department
70525

energy conservation division
B.C. Hydro

ADD-ON HEAT PUMP HYBRID

HEATING SYSTEMS

(PRELIMINARY)

INTRODUCTION

Rapidly increasing oil prices have led many homeowners to seek a less expensive space heating alternative. The Federal Government Canadian Oil Substitution Program adds a further incentive. One alternative which is very attractive in areas not served with natural gas is the oil furnace/electric heat pump add-on hybrid heating system. This system takes advantage of the efficiency of the heat pump, but at the same time retains the existing oil furnace (assuming it is in good condition) to be used in the coldest weather, thus allowing the heat pump to be used with an existing 100 amp electrical service in most cases. This data sheet discusses the oil/ electric hybrid heat pump system specifically, however, other fuels such as natural gas and propane are also used in hybrid heat pump systems.

DESCRIPTION

The heat pump is a device which takes heat from a source such as outside air, a lake, a river or well water and transfers it inside, thus heating the home. It can also cool the home in summer by removing heat from the indoor air and rejecting it outdoors.

Further information on heat pump operations and systems can be obtained from B. C. Hydro Data Sheet E 1800, and the ASHRAE 1979 Equipment Handbook, Chapter 43 and 1980 Systems Handbook, Chapter 11.

The efficiency of the heat pump as a heating system varies directly with the outdoor temperature. The warmer it is outdoors, the more heat the unit can transfer to the indoors. As the outdoor temperature drops, the amount of heat required to heat a home increases, but the amount of heat the heat pump can provide declines. Due to this characteristic, it is not usually practical to size the heat pump to meet the entire heating load of the home. The temperature below which the heat pump can no longer meet the heating requirement is called the balance point temperature.

In order to heat the house below the balance point temperature and to provide heat when the heat pump is in the defrost mode, heat pump systems require some form of auxiliary heat. This is usually supplied as electric resistance heaters built into the unit.

A typical home using an oil furnace for space heating does not have an electric service of adequate capacity to permit the addition of the necessary electric resistance heat. However, if the oil furnace is in good condition, it may be used to provide the necessary auxiliary heat at a minimum cost. Such a system, combining the furnace with a heat pump, is referred to as an Add-On Heat Pump Hybrid heating system.

Add-On oil/electric heat pump hybrid systems generally consist of an oil fired furnace combined with an air-source electric heat pump. A typical system is shown in Figure 1.

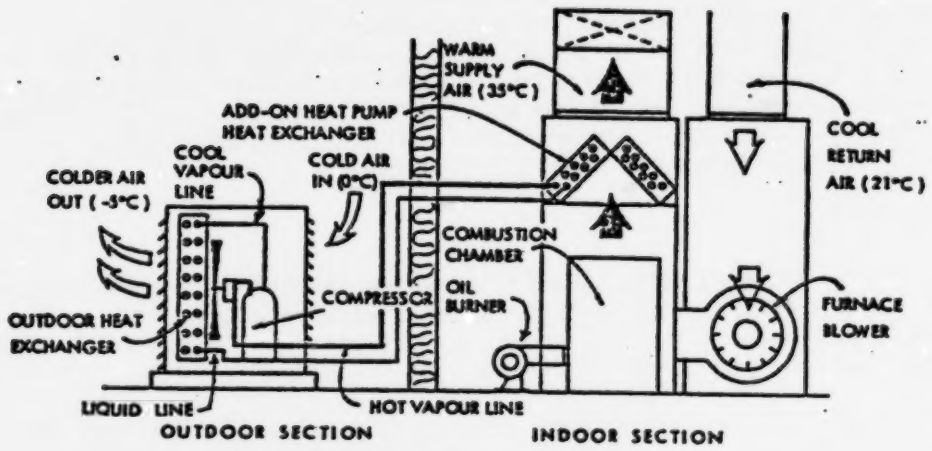


Figure 1

Add-On Hybrid Heat Pump Arrangement[1]
Heating Mode

OPERATION

Above the balance point, the heat pump meets all the heating load and the furnace does not fire (except that some systems are designed such that the furnace does fire for short periods when the heat pump goes into a defrost mode). Below the balance point, the heat pump is shut off and the furnace fires to supply the entire heating load. Note that the furnace and the heat pump compressor do not operate simultaneously, and that for a well designed system, the balance point temperature is low enough that the heat pump supplies most of the heat required over a heating season. Oil use is therefore greatly reduced.

Some hybrid heat pump systems (not usually add-ons) have the heat pump indoor coil located in the return air duct upstream of the furnace. These have the advantage that they can operate as a heat pump and furnace simultaneously and thus make full use of the advantages of the heat pump. However, special consideration must be given to air flow rates and to possible corrosion of the furnace heat exchanger when operating the heat pump in the cooling mode.

PERFORMANCE

The Coefficient of Performance (COP) of the electric heat pump is the ratio of energy output to energy input. It varies from about 1.1 to 3.5. At a COP of 3, for every kW.h used, 3 kW.h can be supplied as heat to the building. The COP declines as the outdoor temperature drops, so whereas the COP may be 2.0 at 5^{o}C, it can drop to 1.5 at -12^{o}C and to 1.1 at -25^{o}C (figures vary with manufacturers and models).

The electric heat pump portion of the hybrid system is not required to operate at temperatures below the balance point. As a result, the average COP of this part of the system should be quite high - probably in the range of 2.0-2.5 for the lower mainland and Vancouver Island, and 1.75-2.25 for all but the coldest regions of the province.

Even at temperatures well above freezing, the exterior coils of a heat pump can frost up. If allowed to build up, the frost reduces the efficiency of the unit and will eventually block off all the air passages. To prevent this the unit must go through a defrost cycle at periodic intervals and this requires energy which will not be available to heat the building (thus reducing the effective COP). Also, provision must be made to drain defrost water and prevent ice build-up.

ADVANTAGES OF HYBRID HEAT PUMPS

The main advantage of the heat pump in general is that it not only converts electrical energy into heat, but also transfers heat from outdoors to inside the house. This transfer of heat allows the system to supply more energy than it uses. It is therefore, a very efficient heating system.

A second advantage of most heat pump systems is that they can also operate as air conditioners. Although this may be of little value to well designed, correctly oriented homes in the coastal areas of British Columbia, it is generally considered to be a desirable feature in those areas of the province which get higher summer temperatures.

Hybrid add-on heat pump systems have some special advantages as well:

- they can make use of existing furnaces thus saving several hundred dollars over the installed cost of a complete new heat pump system;

- with careful attention to sizing of the heat pump and analysis of the home's electrical service requirements, it may be possible to operate on a standard 100 amp residential electrical service.

ECONOMICS

Due to rapidly escalating oil prices, oil space heating has become an expensive heating method. A typical oil furnace in good condition may show a combustion efficiency of 75%-80%, but on a seasonal basis, due to cycling losses, dirt and soot build-up, minor misadjustments, etc., it will probably have an efficiency of 55%-65%. At 63% efficiency, with furnace oil prices of approximately 25¢/litre, one kilowatt hour (kW.h) heat energy supplied to the home by an oil fired heating system will cost about 3.66¢.

A heat pump having an average COP of 2.0 could supply 1 kW.h to the home for a cost of only 1.55¢ with electricity costing 3.1¢/kW.h. The heat pump is therefore attractive in terms of annual energy costs.

Heat pumps are more expensive to buy than other common heating systems. They are also more complicated and generally require more servicing. Maintenance contracts are available from most suppliers. Data Sheet H 309 compares the life cycle costs of electric heat pump systems with the costs of other residential heating systems.

A decision on whether to use an add-on heat pump should take into account individual circumstances and will depend on the answers to the following questions.

- Is natural gas available? If so, it may be a less expensive alternative.
- Does the existing heating system operate satisfactorily to produce comfortable conditions?
- Will a new electric service be required for the heat pump?
- Will major modifications to existing ductwork be required?

- How long are the existing furnace and oil tank expected to last?
- What is the expected total annual energy cost?
- What is the expected total annual maintenance cost?
- Is reliable servicing for the heat pump readily available?
- What value is attached to having air conditioning?

INSTALLATION TIPS

Correct sizing and installation of heat pumps is very important. Sizing will depend on the house heat loss, the air conditioning load and possibly on the electrical service capacity. A unit that is undersized will result in excessive use of the alternate fuel. A unit that is greatly oversized for the cooling load may have operating problems on the air conditioning cycle.

Most homes will require a unit in the 2 Ton to 4 Ton range. Units are commonly available from 1½ Tons to 5 Tons in ½ Ton increments. Larger units are also available.

The designer or equipment supplier should determine the necessary heating and cooling loads, the balance point temperature, the required air flow rate, and any necessary changes to existing ductwork. The manufacturer's recommendations must be followed.

AVAILABILITY

Data Sheet E 1802 indicates a number of sources for heat pumps in general. Of these, Canadian General-Electric, Carrier Western, Westinghouse Canada Ltd., Lennox Industries Ltd. and York supply add-on type hybrid systems.

REFERENCES

1. "The Cost of Owning and Operating a Residential Heat Pump System in Canada", R.L.D. Cane, National Research Council, Division of Building Research, DBR Paper No. 905.

2. B. C. Hydro Energy Use Engineering Data Sheet E 1800 and Project 8011.

INSTALLATIONS

The information shown herein is a guideline only. B. C. Hydro is not responsible for installations. Installations are the responsibility of the installer and should meet the current requirements of the owner, manufacturer's instructions and all applicable regulations.

May 1981: JMB
Energy Use Engineering Department

Energy Conservation Division
B. C. Hydro

APPENDIX C

HEAT PUMP OPERATING CYCLE

HEAT PUMP OPERATING CYCLE

The basic heat pump system consists the following components; compressor, condenser, expansion device and evaporator (Figure i). Its operating cycle is similar to the common household refrigerator except that its main purpose is to provide heat. By reversing the refrigerant flow via the reversing device in the piping circuit, the heat pump would also provide cooling to the house during the summer months.

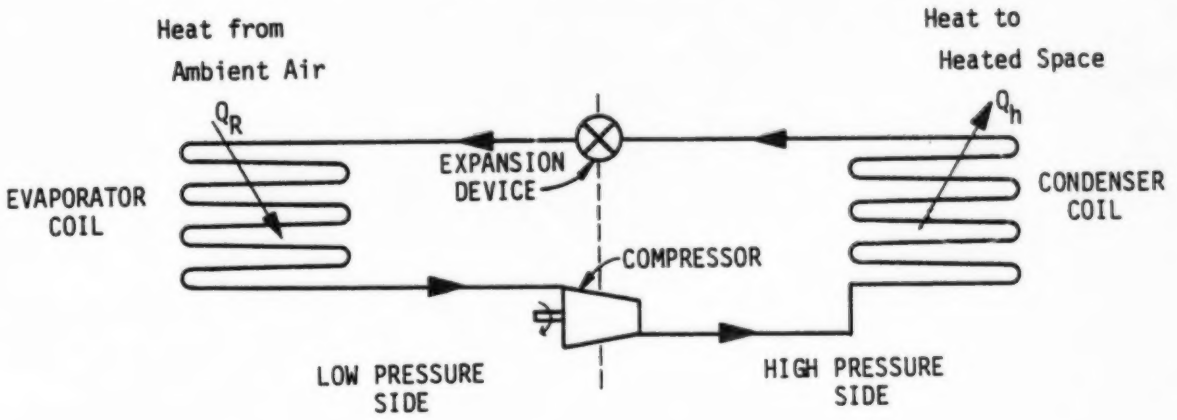


Figure i: Heat Pump System Schematic Diagram

The ideal thermodynamic cycle for the operation of the heat pump is the reversed Carnot cycle (Figure ii). The expansion device in Figure i is replaced by an ideal expansion machine where work is performed when the refrigerant liquid pressure is lowered.

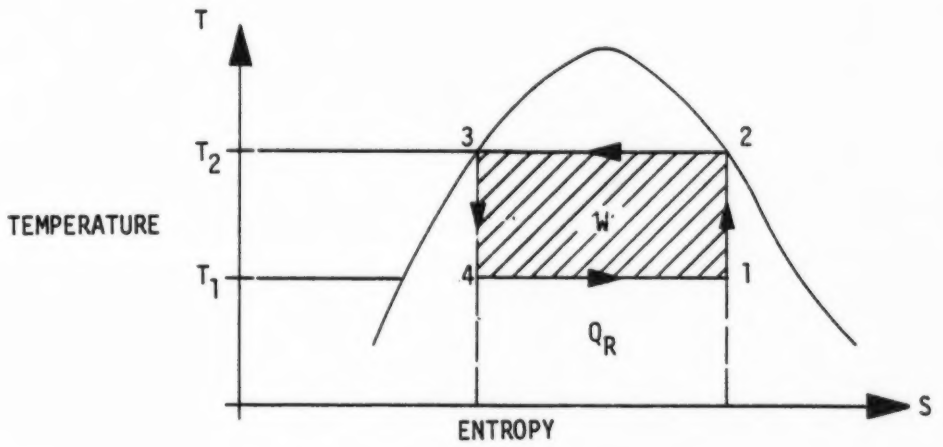


Figure ii: Temperature - Entropy Diagram
For Reversed Carnot Cycle

The refrigerant vapor/liquid mixture in the ideal cycle at point 1 is compressed reversibly and adibatically (isentropically) by the compressor. It leaves the compressor at point 2 as high temperature, high pressure, saturated vapor. Then it enters the condenser (indoor coil) where heat is transferred to the warm air in the home. The vapor would be cooled and condensed to saturated liquid state at constant pressure. From point 3, it leaves the condenser and enters the expansion device. It is expanded isentropically to a lower pressure, lower temperature and lower quality vapor and enters the evaporator (outdoor coil) at point 4, where it is evaporated (by the heat from the outdoor air) at constant pressure to its original point 1. Since the system is cyclic, the heat (Q_h) gained from the condenser must be equal to the work of compression (W) and the heat (Q_R) absorbed by the evaporator.

$$\text{i.e. } Q_h = W + Q_R \qquad \text{(equ. 1)}$$

The Coefficient Of Performance (COP) is a measure which is commonly used to evaluate the performance of refrigeration system. For a heat pump, the COP for heating is defined as the ratio of heat gained from the system to the work of compression.

$$\text{i.e. } COP_{hp} = \frac{Q_h}{W}$$

From equation 1;

$$COP_{hp} = \frac{W + Q_R}{W}$$

$$= 1 + \frac{Q_R}{W}$$

$$= 1 + \frac{T_1}{T_2 - T_1} \qquad \text{(equ. 2)}$$

Equation 2 shows the COP_{hp} is always greater than unity and since the processes are mainly transfer of heat energy, the term efficiency is not used. This equation also shows that as temperature T_1 goes lower (ambient temperature), the larger the temperature difference term, $T_2 - T_1$, resulting in lower COP_{hp}. Unfortunately, the heating requirement of a home increases as the ambient temperature decreases. Hence heat pump heating systems require supplementary heat (usually electric resistance heaters) when the ambient temperature is below the point (balance point) where the heat pump is no longer capable of providing the heating requirement of the house.

For an air-to-air heat pump applied to maintain a house at 21°C (condensing temperature) and the ambient temperature (evaporating temperature) at 7°C, the COP_{hp} is 21.2 assuming an ideal Carnot cycle (equ. 2). This means that ideally for each kilowatt of compressor work, a corresponding 21.2 kilowatts of heat will be delivered.

JR38.2

ENERGY SAVINGS FORECAST WITH INCREASED USE OF HEAT PUMPS

PROBABLE - 1985

REGION	# OF ACCOUNTS FORECAST		1980 CONSUMPTION PER ELEC HTG ACC			FORECAST		Z	SAVINGS IN kWhr/yr		
	HTG	RESID.	TOTAL	L&A.	H.W	SPACE HTG	SPF	PENET.	TOTAL	PER ACC HTG	RES
Metro	35400	381100	14046	4775	4580	4053	2.0	0.00	0	0	0
Fraser Valley	16000	194200	17676	4775	4580	7548	2.0	0.00	0	0	0
Central Interior	12100	90900	19762	4775	4580	9777	1.6	0.00	0	0	0
North Coast	6900	29000	20959	4775	4580	11243	2.0	0.00	0	0	0
Southern Interior	24500	120900	17222	4775	4580	7500	2.0	1.00	918762	38	8
Vanc. Island	71300	216900	16879	4775	4580	6508	2.0	0.50	1160000	16	5
ALL HYDRO	166200	1033000							2078770	13	2

PROBABLE - 1990

REGION	# OF ACCOUNTS FORECAST		1980 CONSUMPTION PER ELEC HTG ACC			FORECAST		Z	SAVINGS IN kWhr/yr		
	HTG	RESID.	TOTAL	L&A.	H.W	SPACE HTG	SPF	PENET.	TOTAL	PER ACC HTG	RES
Metro	53000	438300	14046	4775	4580	3554	2.1	0.50	493383	9	1
Fraser Valley	21800	237200	17676	4775	4580	7025	2.1	0.50	401080	18	2
Central Interior	16900	111100	19762	4775	4580	8918	1.7	0.25	155154	9	1
North Coast	8700	34200	20959	4775	4580	10680	2.1	0.50	243349	28	7
Southern Interior	31500	145100	17222	4775	4580	7161	2.1	2.00	2363140	75	16
Vanc. Island	91500	257100	16879	4775	4580	6062	2.1	1.90	5520050	60	21
ALL HYDRO	223400	1223000							9176160	41	8

In practice, the expansion device is replaced by an expansion valve and also it will be difficult for the evaporation process to stop at point 1 (Figure ii). Moreover, it is undesirable for any liquid refrigerant to pass into the compressor which would wash away the lubricating oil. A more practical ideal cycle is the Rankine cycle (Figure iii), where the refrigerant is heated to the saturated vapor (gas) state at point 1' in the evaporator. The compression of the refrigerant vapor from point 1' to 2', would then be carried out in the superheat region. The theorectical COP for the heat pump is reduced from 21.2 (Carnot cycle) to around 5 for the Rankine cycle.

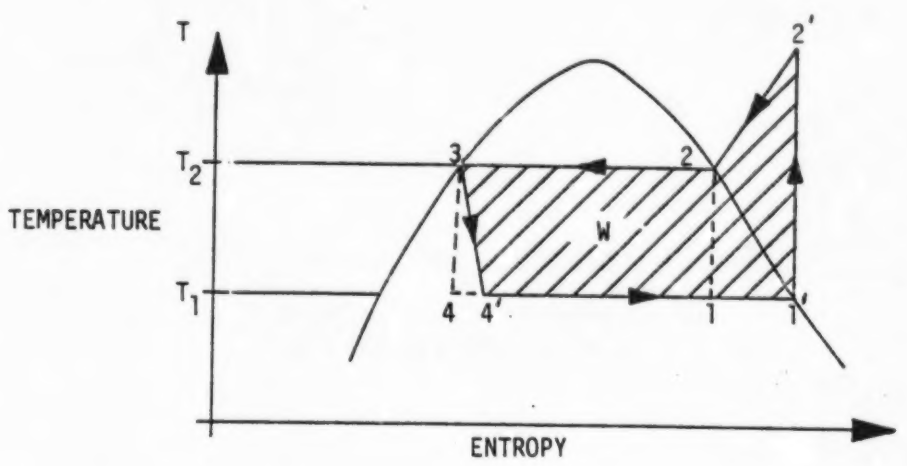


Figure iii: Temperature - Entropy Diagram
For Reversed Rankine Cycle

The actual compression and expansion processes in a practical heat pump cycle are not reversible and do not occur at constant entropy which make the whole thermodynamic cycle irreversible. Also there are losses in the heat pump systems due to fan power required to move the air over the indoor and outdoor coils, energy required to defrost the outdoor coil, pressure losses in piping, valves, etc., temperature gradients in the heat exchangers, and inefficiency of the compressor and motor. These factors reduce the actual COP of a heat pump about 1.1 to 3 range depending on the operating conditions.

PROBABLE - 1995

REGION	# OF ACCOUNTS FORECAST		1980 CONSUMPTION PER ELEC HTG ACC			FORECAST SPACE	SPF	%	SAVINGS IN kWhr/yr TOTAL	PER ACC	
	HTG	RESID.	TOTAL	L&A.	H.W	HTG		PENET.		HTG	RES
Metro	65000	472700	14046	4775	4580	3290	2.2	1.50	1749740	27	4
Fraser Valley	32000	255800	17676	4775	4580	6457	2.2	1.50	1690520	53	7
Central Interior	21000	119800	19762	4775	4580	7884	1.8	0.50	367939	18	3
North Coast	10000	36900	20959	4775	4580	10040	2.2	1.50	821436	82	22
Southern Interior	38000	156500	17222	4775	4580	6811	2.2	4.00	5646610	149	36
Vanc. Island	112000	277300	16879	4775	4580	5689	2.2	3.00	10426800	93	38
ALL HYDRO	278000	1319000							20703100	74	16

PROBABLE - 2005

REGION	# OF ACCOUNTS FORECAST		1980 CONSUMPTION PER ELEC HTG ACC			FORECAST SPACE	SPF	%	SAVINGS IN kWhr/yr TOTAL	PER ACC	
	HTG	RESID.	TOTAL	L&A.	H.W	HTG		PENET.		HTG	RES
Metro	80000	514300	14046	4775	4580	2821	2.4	3.00	3948760	49	8
Fraser Valley	43000	278300	17676	4775	4580	5800	2.4	3.00	4364640	102	16
Central Interior	29000	130300	19762	4775	4580	6444	2.0	1.00	934371	32	7
North Coast	13000	40100	20959	4775	4580	8915	2.4	3.00	2028270	156	51
Southern Interior	45000	170200	17222	4775	4580	6264	2.3	10.00	15932700	354	94
Vanc. Island	140000	301800	16879	4775	4580	4998	2.4	8.00	32650700	233	108
ALL HYDRO	350000	1435000							59859500	171	42

APPENDIX D

PRELIMINARY DATA SHEET H 309

RELATIVE ENERGY CONSUMPTIONS AND COSTS FOR RESIDENTIAL SPACE HEATING

PRELIMINARY DATA SHEET H 309
RELATIVE ENERGY CONSUMPTIONS AND COSTS FOR RESIDENTIAL SPACE HEATING

A life cycle cost analysis is a common method used in the economic evaluation of the various heating systems which involves complex factors like fuel costs, inflation rate, interest rate, capital cost, maintenance charges, replacement and depreciation values of equipment over the life time of the equipment or house.

A computer program is being developed by Energy Use Engineering Department using the life cycle cost method for evaluating six heating systems - gas/oil/electric forced air furnaces, electric baseboard/ceiling cable and electric heat pump, in the five Hydro regions. The annual space heating energy consumption is based on a typical 1,200 square foot house with conventional insulation (R7 ceiling and walls, single glazing except for Central Interior and North Coast regions which would have double glazing). A comparison is also presented for the same house with higher insulation levels (R28 ceiling, R12 walls, double glazing with Central Interior and North Coast regions having triple glazing). The projected average annual rate of fuel cost increase, inflation rate and interest rate are obtained from Hydro Corporate Economist office*. The SPF for the heat pump is assumed to be 2 for all regions except for Central and Southern Interior regions where it is 1.6 and 1.9 respectively.

The results of this analysis presented for each region in the following pages show that the electric heat pump annual energy consumption and costs are the lowest in comparison to all the other heating systems in all regions. But due to the higher initial cost of a heat pump, a gas furnace heating system has the lowest life cycle cost in the regions where natural gas service is available.

* T. Gouveia, Private Communications.

PRELIMINARY
RELATIVE ENERGY CONSUMPTIONS AND COSTS
FOR RESIDENTIAL SPACE HEATING
FOR TYPICAL 1200 SQ.FT. HOUSE FROM H308

H309-
1982 JUL 5

LOWER MAINLAND

CONDITIONS
ANNUAL RATE OF FUEL COST INCREASE GAS 0.10 OIL 0.12 ELEC 0.10 LIFE 25 YRS
ANNUAL INFLATION RATE 0.09 ANNUAL INTEREST RATE 0.15 EQUIP. SALVAGE VALUE 0.05

HOUSE 1: WITH CONVENTIONAL INSULATION

	GAS FURNACE	OIL FURNACE	ELECTRIC BASE-BOARD	ELECTRIC CEILING CABLE	ELECTRIC FURNACE	ELECTRIC HEAT PUMP
ENERGY USE	CU.FT.	GALS.	KWH	KWH	KWH	KWH
ANNUAL FUEL USE	126502	893	20310	20310	24372	12186
EQUIVALENT THERMS	1265	1500	693	693	832	416
EQUIVALENT KWH	37076	43962	20310	20310	24372	12186
25-YEAR FUEL USE (KWH)	926.9	1099.1	507.7	507.7	609.3	304.6
USAGE RATE (KWH/SQ.METRE/YEAR)	166.3	197.2	91.1	91.1	109.3	54.7
RELATIVE PERCENT	100	119	55	55	66	33
ENERGY COST						
CURRENT ANNUAL FUEL COST ($)	569	1195	763	763	916	458
RELATIVE PERCENT	100	210	134	134	161	80
PROJECTED 25-YEAR FUEL COST ($)	55959	159334	75039	75039	90047	45023
RELATIVE PERCENT	100	285	134	134	161	80
25-YEAR OWNING AND OPERATING COSTS						
ORIGINAL EQUIPMENT INSTALLED COST ($)	2000	2400	1700	1800	2000	5500
SERVICE AND MAINTENANCE COST ($)	200	1050	63	25	200	1625
EQUIPMENT LIFE (YEARS)	20	15	25	25	25	12
CURRENT EQUIP. REPLACEMENT COST ($)	800	900	1300	1800	800	2000
PRESENT VALUE OF EQUIPMENT REPLACEMENT ($)	144	348	0	0	0	1174
PRESENT VALUE OF FUEL COST, 25 YEARS ($)	8398	21574	11261	11261	13513	6757
TOTAL 25-YEAR LIFE CYCLE COST ($)	10742	25372	13024	13086	15713	15055
RELATIVE PERCENT	100	236	121	122	146	140

HOUSE 2: WITH RECOMMENDED INSULATION

	GAS FURNACE	OIL FURNACE	ELECTRIC BASE-BOARD	ELECTRIC CEILING CABLE	ELECTRIC FURNACE	ELECTRIC HEAT PUMP
ENERGY USE	CU.FT.	GALS.	KWH	KWH	KWH	KWH
ANNUAL FUEL USE	101523	704	16137	16137	19364	9682
EQUIVALENT THERMS	1015	1183	551	551	661	330
EQUIVALENT KWH	29755	34664	16137	16137	19364	9682
25-YEAR FUEL USE (KWH)	743.9	866.6	403.4	403.4	484.1	242.1
USAGE RATE (KWH/SQ.METRE/YEAR)	133.4	155.5	72.4	72.4	86.8	43.4
RELATIVE PERCENT	100	116	54	54	65	33
ENERGY COST						
CURRENT ANNUAL FUEL COST ($)	467	942	606	606	727	364
RELATIVE PERCENT	100	202	130	130	156	78
PROJECTED 25-YEAR FUEL COST ($)	45928	125601	59598	59598	71518	35759
RELATIVE PERCENT	100	273	130	130	156	78
25-YEAR OWNING AND OPERATING COSTS						
ORIGINAL EQUIPMENT INSTALLED COST ($)	1900	2400	1500	1500	1900	5000
SERVICE AND MAINTENANCE COST ($)	200	1050	63	25	200	1625
EQUIPMENT LIFE (YEARS)	20	15	25	25	25	12
CURRENT EQUIP. REPLACEMENT COST ($)	700	800	1000	1500	800	1800
PRESENT VALUE OF EQUIPMENT REPLACEMENT ($)	126	310	0	0	0	1056
PRESENT VALUE OF FUEL COST, 25 YEARS ($)	6892	17006	8944	8944	10733	5366
TOTAL 25-YEAR LIFE CYCLE COST ($)	9119	20766	10507	10469	12833	13048
RELATIVE PERCENT	100	228	115	115	141	143
RELATIVE PERCENT HOUSE 1 OVER HOUSE 2	118	278	143	144	172	165

H.M.L. 1982 JUL 5
HEATING AND AIR CONDITIONING SECTION
ENERGY USE ENGINEERING

ENERGY CONSERVATION DIVISION
B.C. HYDRO

PRELIMINARY
RELATIVE ENERGY CONSUMPTIONS AND COSTS
FOR RESIDENTIAL SPACE HEATING
FOR TYPICAL 1200 SQ.FT. HOUSE FROM H308

H309-
1982 JUL 5

VANCOUVER ISLAND

CONDITIONS
ANNUAL RATE OF FUEL COST INCREASE GAS 0.10 OIL 0.12 ELEC 0.10 LIFE 25 YRS
ANNUAL INFLATION RATE 0.09 ANNUAL INTEREST RATE 0.15 EQUIP. SALVAGE VALUE 0.05

HOUSE 1: WITH CONVENTIONAL INSULATION

	GAS FURNACE	OIL FURNACE	ELECTRIC BASE-BOARD	ELECTRIC CEILING CABLE	ELECTRIC FURNACE	ELECTRIC HEAT PUMP
ENERGY USE						
ANNUAL FUEL USE	CU.FT.	GALS.	KWH	KWH	KWH	KWH
EQUIVALENT THERMS	123123	867	19750	19750	23700	11850
EQUIVALENT KWH	1231	1457	674	674	809	404
25-YEAR FUEL USE (KWH)	36085	42704	19750	19750	23700	11850
USAGE RATE (KWH/SQ.METRE/YEAR)	902.1	1067.6	493.7	493.7	592.5	296.2
RELATIVE PERCENT	161.8	191.5	88.6	88.6	106.3	53.1
	100	118	55	55	66	33
ENERGY COST						
CURRENT ANNUAL FUEL COST ($)	1054	1171	742	742	890	445
RELATIVE PERCENT	100	111	70	70	84	42
PROJECTED 25-YEAR FUEL COST ($)	103658	156134	72974	72974	87568	43784
RELATIVE PERCENT	100	151	70	70	84	42
25-YEAR OWNING AND OPERATING COSTS						
ORIGINAL EQUIPMENT INSTALLED COST ($)	2000	2400	1700	1800	2000	5500
SERVICE AND MAINTENANCE COST ($)	200	1050	63	25	200	1625
EQUIPMENT LIFE (YEARS)	20	15	25	25	25	12
CURRENT EQUIP. REPLACEMENT COST ($)	800	900	1300	1800	800	2000
PRESENT VALUE OF EQUIPMENT REPLACEMENT ($)	144	348	0	0	0	1174
PRESENT VALUE OF FUEL COST, 25 YEARS ($)	15556	21141	10951	10951	13141	6571
TOTAL 25-YEAR LIFE CYCLE COST ($)	17900	24939	12714	12776	15341	14869
RELATIVE PERCENT	100	139	71	71	86	83

HOUSE 2: WITH RECOMMENDED INSULATION

	GAS FURNACE	OIL FURNACE	ELECTRIC BASE-BOARD	ELECTRIC CEILING CABLE	ELECTRIC FURNACE	ELECTRIC HEAT PUMP
ENERGY USE						
ANNUAL FUEL USE	CU.FT.	GALS.	KWH	KWH	KWH	KWH
EQUIVALENT THERMS	98859	684	15692	15692	18830	9415
EQUIVALENT KWH	989	1149	535	535	642	321
25-YEAR FUEL USE (KWH)	28974	33672	15692	15692	18830	9415
USAGE RATE (KWH/SQ.METRE/YEAR)	724.3	841.8	392.3	392.3	470.8	235.4
RELATIVE PERCENT	129.9	151.0	70.4	70.4	84.4	42.2
	100	116	54	54	65	32
ENERGY COST						
CURRENT ANNUAL FUEL COST ($)	885	923	590	590	708	354
RELATIVE PERCENT	100	104	67	67	80	40
PROJECTED 25-YEAR FUEL COST ($)	87037	123067	58025	58025	69630	34815
RELATIVE PERCENT	100	141	67	67	80	40
25-YEAR OWNING AND OPERATING COSTS						
ORIGINAL EQUIPMENT INSTALLED COST ($)	1900	2400	1500	1500	1900	5000
SERVICE AND MAINTENANCE COST ($)	200	1050	63	25	200	1625
EQUIPMENT LIFE (YEARS)	20	15	25	25	25	12
CURRENT EQUIP. REPLACEMENT COST ($)	700	800	1000	1500	800	1800
PRESENT VALUE OF EQUIPMENT REPLACEMENT ($)	126	310	0	0	0	1056
PRESENT VALUE OF FUEL COST, 25 YEARS ($)	13062	16663	8708	8708	10449	5225
TOTAL 25-YEAR LIFE CYCLE COST ($)	15288	20423	10270	10233	12549	12906
RELATIVE PERCENT	100	134	67	67	82	84
RELATIVE PERCENT HOUSE 1 OVER HOUSE 2	117	163	83	84	100	97

H.M.L. 1982 JUL 5
HEATING AND AIR CONDITIONING SECTION
ENERGY USE ENGINEERING

ENERGY CONSERVATION DIVISION
B.C. HYDRO

PRELIMINARY
RELATIVE ENERGY CONSUMPTIONS AND COSTS
FOR RESIDENTIAL SPACE HEATING
FOR TYPICAL 1200 SQ.FT. HOUSE FROM H308

H309-
1982 JUL 5

CENTRAL INTERIOR

CONDITIONS
ANNUAL RATE OF FUEL COST INCREASE GAS 0.10 OIL 0.12 ELEC 0.10 LIFE 25 YRS
ANNUAL INFLATION RATE 0.09 ANNUAL INTEREST RATE 0.15 EQUIP. SALVAGE VALUE 0.05

HOUSE 1: WITH CONVENTIONAL INSULATION

	GAS FURNACE	OIL FURNACE	ELECTRIC BASE-BOARD	ELECTRIC CEILING CABLE	ELECTRIC FURNACE	ELECTRIC HEAT PUMP
ENERGY USE	CU.FT.	GALS.	KWH	KWH	KWH	KWH
ANNUAL FUEL USE	196783	1424	28654	28654	34385	21491
EQUIVALENT THERMS	1968	2393	978	978	1173	733
EQUIVALENT KWH	57674	70124	28654	28654	34385	21490
25-YEAR FUEL USE (MWH)	1441.8	1753.1	716.3	716.3	859.6	537.3
USAGE RATE (KWH/SQ.METRE/YEAR)	258.7	314.5	128.5	128.5	154.2	96.4
RELATIVE PERCENT	100	122	50	50	60	37
ENERGY COST						
CURRENT ANNUAL FUEL COST ($)	748	2001	1077	1077	1292	808
RELATIVE PERCENT	100	268	144	144	173	108
PROJECTED 25-YEAR FUEL COST ($)	73564	266801	105920	105920	127104	79440
RELATIVE PERCENT	100	363	144	144	173	108
25-YEAR OWNING AND OPERATING COSTS						
ORIGINAL EQUIPMENT INSTALLED COST ($)	2000	2400	1700	1800	2000	5500
SERVICE AND MAINTENANCE COST ($)	200	1050	63	25	200	1625
EQUIPMENT LIFE (YEARS)	20	15	25	25	25	12
CURRENT EQUIP. REPLACEMENT COST ($)	800	900	1300	1800	800	2000
PRESENT VALUE OF EQUIPMENT REPLACEMENT ($)	144	348	0	0	0	1174
PRESENT VALUE OF FUEL COST, 25 YEARS ($)	11040	36125	15896	15896	19075	11922
TOTAL 25-YEAR LIFE CYCLE COST ($)	13384	39923	17658	17721	21275	20220
RELATIVE PERCENT	100	298	132	132	159	151

HOUSE 2: WITH RECOMMENDED INSULATION

	GAS FURNACE	OIL FURNACE	ELECTRIC BASE-BOARD	ELECTRIC CEILING CABLE	ELECTRIC FURNACE	ELECTRIC HEAT PUMP
ENERGY USE	CU.FT.	GALS.	KWH	KWH	KWH	KWH
ANNUAL FUEL USE	152713	1091	22352	22352	26822	16764
EQUIVALENT THERMS	1527	1833	763	763	915	572
EQUIVALENT KWH	44758	53719	22352	22352	26822	16764
25-YEAR FUEL USE (MWH)	1118.9	1343.0	558.8	558.8	670.6	419.1
USAGE RATE (KWH/SQ.METRE/YEAR)	200.7	240.9	100.2	100.2	120.3	75.2
RELATIVE PERCENT	100	120	50	50	60	37
ENERGY COST						
CURRENT ANNUAL FUEL COST ($)	593	1533	840	840	1008	630
RELATIVE PERCENT	100	259	142	142	170	106
PROJECTED 25-YEAR FUEL COST ($)	58320	204401	82612	82612	99134	61959
RELATIVE PERCENT	100	350	142	142	170	106
25-YEAR OWNING AND OPERATING COSTS						
ORIGINAL EQUIPMENT INSTALLED COST ($)	1900	2400	1500	1500	1900	5000
SERVICE AND MAINTENANCE COST ($)	200	1050	63	25	200	1625
EQUIPMENT LIFE (YEARS)	20	15	25	25	25	12
CURRENT EQUIP. REPLACEMENT COST ($)	700	800	1000	1500	800	1800
PRESENT VALUE OF EQUIPMENT REPLACEMENT ($)	126	310	0	0	0	1056
PRESENT VALUE OF FUEL COST, 25 YEARS ($)	8752	27676	12398	12398	14877	9298
TOTAL 25-YEAR LIFE CYCLE COST ($)	10978	31436	13960	13923	16977	16979
RELATIVE PERCENT	100	286	127	127	155	155
RELATIVE PERCENT HOUSE 1 OVER HOUSE 2	122	364	161	161	194	184

H.M.L. 1982 JUL 5
HEATING AND AIR CONDITIONING SECTION
ENERGY USE ENGINEERING

ENERGY CONSERVATION DIVISION
B.C. HYDRO

PRELIMINARY

RELATIVE ENERGY CONSUMPTIONS AND COSTS
FOR RESIDENTIAL SPACE HEATING
FOR TYPICAL 1200 SQ.FT. HOUSE FROM M308

M309-
1982 JUL 5

SOUTHERN INTERIOR

CONDITIONS

ANNUAL RATE OF FUEL COST INCREASE GAS 0.10 OIL 0.12 ELEC 0.10 LIFE 25 YRS
ANNUAL INFLATION RATE 0.09 ANNUAL INTEREST RATE 0.15 EQUIP. SALVAGE VALUE 0.05

HOUSE 1: WITH CONVENTIONAL INSULATION

	GAS FURNACE	OIL FURNACE	ELECTRIC BASE-BOARD	ELECTRIC CEILING CABLE	ELECTRIC FURNACE	ELECTRIC HEAT PUMP
ENERGY USE	CU.FT.	GALS.	KWH	KWH	KWH	KWH
ANNUAL FUEL USE	147815	1054	21463	21463	25756	13522
EQUIVALENT THERMS	1478	1771	732	732	879	461
EQUIVALENT KWH	43322	51896	21463	21463	25756	13522
25-YEAR FUEL USE (MWH)	1083.1	1297.4	536.6	536.6	643.9	338.0
USAGE RATE (KWH/SQ.METRE/YEAR)	194.3	232.7	96.3	96.3	115.5	60.6
RELATIVE PERCENT	100	120	50	50	59	31
ENERGY COST						
CURRENT ANNUAL FUEL COST ($)	572	1446	807	807	968	508
RELATIVE PERCENT	100	253	141	141	169	89
PROJECTED 25-YEAR FUEL COST ($)	56255	192801	79366	79366	95239	50001
RELATIVE PERCENT	100	343	141	141	169	89
25-YEAR OWNING AND OPERATING COSTS						
ORIGINAL EQUIPMENT INSTALLED COST ($)	2000	2400	1700	1800	2000	5500
SERVICE AND MAINTENANCE COST ($)	200	1050	63	25	200	1625
EQUIPMENT LIFE (YEARS)	20	15	25	25	25	12
CURRENT EQUIP. REPLACEMENT COST ($)	800	900	1300	1800	800	2000
PRESENT VALUE OF EQUIPMENT REPLACEMENT ($)	144	348	0	0	0	1174
PRESENT VALUE OF FUEL COST, 25 YEARS ($)	8442	26105	11911	11911	14293	7504
TOTAL 25-YEAR LIFE CYCLE COST ($)	10787	29904	13673	13736	16493	15802
RELATIVE PERCENT	100	277	127	127	153	146

HOUSE 2: WITH RECOMMENDED INSULATION

	GAS FURNACE	OIL FURNACE	ELECTRIC BASE-BOARD	ELECTRIC CEILING CABLE	ELECTRIC FURNACE	ELECTRIC HEAT PUMP
ENERGY USE	CU.FT.	GALS.	KWH	KWH	KWH	KWH
ANNUAL FUEL USE	115200	807	16737	16737	20084	10544
EQUIVALENT THERMS	1152	1356	571	571	685	360
EQUIVALENT KWH	33763	39755	16737	16737	20084	10544
25-YEAR FUEL USE (MWH)	844.1	993.9	418.4	418.4	502.1	263.6
USAGE RATE (KWH/SQ.METRE/YEAR)	151.4	178.3	75.1	75.1	90.1	47.3
RELATIVE PERCENT	100	118	50	50	59	31
ENERGY COST						
CURRENT ANNUAL FUEL COST ($)	456	1108	629	629	755	396
RELATIVE PERCENT	100	243	138	138	166	87
PROJECTED 25-YEAR FUEL COST ($)	44846	147734	61860	61860	74232	38972
RELATIVE PERCENT	100	329	138	138	166	87
25-YEAR OWNING AND OPERATING COSTS						
ORIGINAL EQUIPMENT INSTALLED COST ($)	1900	2400	1500	1500	1900	5000
SERVICE AND MAINTENANCE COST ($)	200	1050	63	25	200	1625
EQUIPMENT LIFE (YEARS)	20	15	25	25	25	12
CURRENT EQUIP. REPLACEMENT COST ($)	700	800	1000	1500	800	1800
PRESENT VALUE OF EQUIPMENT REPLACEMENT ($)	126	310	0	0	0	1056
PRESENT VALUE OF FUEL COST, 25 YEARS ($)	6730	20003	9283	9283	11140	5849
TOTAL 25-YEAR LIFE CYCLE COST ($)	8956	23763	10846	10808	13240	13530
RELATIVE PERCENT	100	265	121	121	148	151
RELATIVE PERCENT HOUSE 1 OVER HOUSE 2	120	334	153	153	184	176

PRELIMINARY

H309-
1982 JUL 5

RELATIVE ENERGY CONSUMPTIONS AND COSTS
FOR RESIDENTIAL SPACE HEATING
FOR TYPICAL 1200 SQ.FT. HOUSE FROM H308

NORTH COAST

CONDITIONS
ANNUAL RATE OF FUEL COST INCREASE GAS 0.10 OIL 0.12 ELEC 0.10 LIFE 25 YRS
ANNUAL INFLATION RATE 0.09 ANNUAL INTEREST RATE 0.15 EQUIP. SALVAGE VALUE 0.05

HOUSE 1: WITH CONVENTIONAL INSULATION

	GAS FURNACE	OIL FURNACE	ELECTRIC BASE-BOARD	ELECTRIC CEILING CABLE	ELECTRIC FURNACE	ELECTRIC HEAT PUMP
ENERGY USE	CU.FT.	GALS.	KWH	KWH	KWH	KWH
ANNUAL FUEL USE	159846	1145	22909	22909	27491	13745
EQUIVALENT THERMS	1598	1923	782	782	938	469
EQUIVALENT KWH	46848	56374	22909	22909	27491	13745
25-YEAR FUEL USE (MWH)	1171.2	1409.4	572.7	572.7	687.3	343.6
USAGE RATE (KWH/SQ.METRE/YEAR)	210.1	252.8	102.7	102.7	123.3	61.6
RELATIVE PERCENT	100	120	49	49	59	29
ENERGY COST						
CURRENT ANNUAL FUEL COST ($)	642	1608	861	861	1033	517
RELATIVE PERCENT	100	250	134	134	161	80
PROJECTED 25-YEAR FUEL COST ($)	63139	214401	84677	84677	101612	50806
RELATIVE PERCENT	100	340	134	134	161	80
25-YEAR OWNING AND OPERATING COSTS						
ORIGINAL EQUIPMENT INSTALLED COST ($)	2000	2400	1700	1800	2000	5500
SERVICE AND MAINTENANCE COST ($)	200	1050	63	25	200	1625
EQUIPMENT LIFE (YEARS)	20	15	25	25	25	12
CURRENT EQUIP. REPLACEMENT COST ($)	800	900	1300	1800	800	2000
PRESENT VALUE OF EQUIPMENT REPLACEMENT ($)	144	348	0	0	0	1174
PRESENT VALUE OF FUEL COST, 25 YEARS ($)	9475	29030	12708	12708	15249	7625
TOTAL 25-YEAR LIFE CYCLE COST ($)	11820	32828	14470	14533	17449	15923
RELATIVE PERCENT	100	278	122	123	148	135

HOUSE 2: WITH RECOMMENDED INSULATION

	GAS FURNACE	OIL FURNACE	ELECTRIC BASE-BOARD	ELECTRIC CEILING CABLE	ELECTRIC FURNACE	ELECTRIC HEAT PUMP
ENERGY USE	CU.FT.	GALS.	KWH	KWH	KWH	KWH
ANNUAL FUEL USE	124416	877	17865	17865	21438	10719
EQUIVALENT THERMS	1244	1473	610	610	731	366
EQUIVALENT KWH	36464	43186	17865	17865	21438	10719
25-YEAR FUEL USE (MWH)	911.6	1079.6	446.6	446.6	535.9	268.0
USAGE RATE (KWH/SQ.METRE/YEAR)	163.5	193.7	80.1	80.1	96.1	48.1
RELATIVE PERCENT	100	118	49	49	59	29
ENERGY COST						
CURRENT ANNUAL FUEL COST ($)	512	1232	671	671	805	403
RELATIVE PERCENT	100	241	131	131	157	79
PROJECTED 25-YEAR FUEL COST ($)	50354	164267	65991	65991	79189	39595
RELATIVE PERCENT	100	326	131	131	157	79
25-YEAR OWNING AND OPERATING COSTS						
ORIGINAL EQUIPMENT INSTALLED COST ($)	1900	2400	1500	1500	1900	5000
SERVICE AND MAINTENANCE COST ($)	200	1050	63	25	200	1625
EQUIPMENT LIFE (YEARS)	20	15	25	25	25	12
CURRENT EQUIP. REPLACEMENT COST ($)	700	800	1000	1500	800	1800
PRESENT VALUE OF EQUIPMENT REPLACEMENT ($)	126	310	0	0	0	1056
PRESENT VALUE OF FUEL COST, 25 YEARS ($)	7557	22242	9903	9903	11884	5942
TOTAL 25-YEAR LIFE CYCLE COST ($)	9783	26002	11466	11428	13984	13623
RELATIVE PERCENT	100	266	117	117	143	139
RELATIVE PERCENT HOUSE 1 OVER HOUSE 2	121	336	148	149	178	163

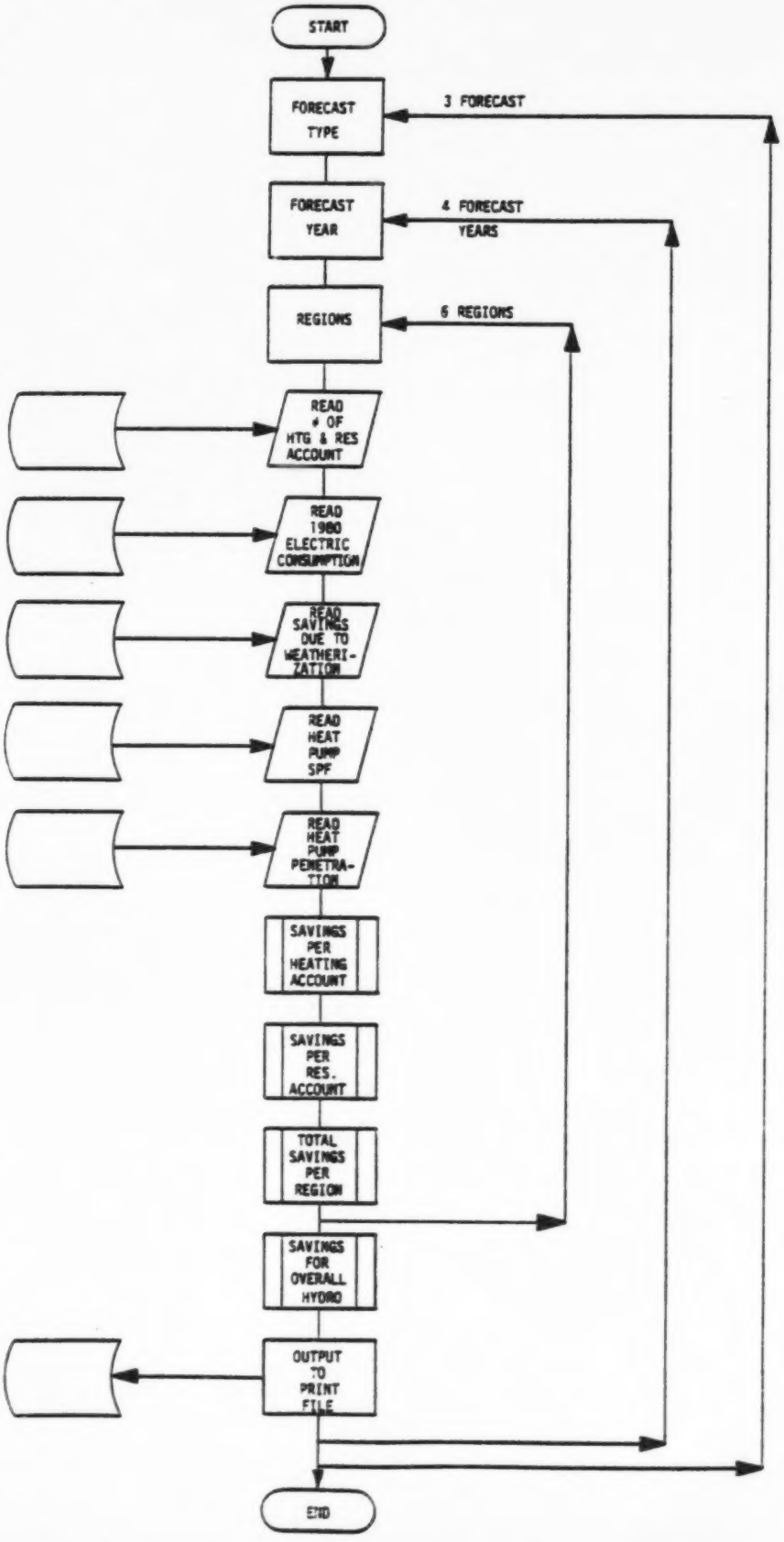
H.M.L. 1982 JUL 5
HEATING AND AIR CONDITIONING SECTION
ENERGY USE ENGINEERING

ENERGY CONSERVATION DIVISION
B.C. HYDRO

APPENDIX E

FLOW CHART OF HEAT PUMP ENERGY SAVINGS FORECAST COMPUTER PROGRAM

FLOW CHART OF HEAT PUMP ENERGY SAVINGS FORECAST COMPUTER PROGRAM



APPENDIX F

FORECAST TABLES TO YEAR 2005

ENERGY SAVINGS FORECAST WITH INCREASED USE OF HEAT PUMPS

PESSIMISTIC - 1985

REGION	# OF ACCOUNTS FORECAST		1980 CONSUMPTION PER ELEC HTG ACC			FORECAST SPACE HTG	SPF	% PENET.	SAVINGS IN kWhr/yr TOTAL	PER ACC HTG	RES
	HTG	RESID.	TOTAL	L&A.	H.W						
Metro	35400	381100	14046	4775	4580	4053	2.0	0.00	0	0	0
Fraser Valley	16000	194200	17676	4775	4580	7548	2.0	0.00	0	0	0
Central Interior	12100	90900	19762	4775	4580	9777	1.6	0.00	0	0	0
North Coast	6900	29000	20959	4775	4580	11243	2.0	0.00	0	0	0
Southern Interior	24500	120900	17222	4775	4580	7500	1.9	0.50	435203	18	4
Vanc. Island	71300	216900	16879	4775	4580	6508	2.0	0.25	580001	8	3
ALL HYDRO	166200	1033000							1015200	6	1

PESSIMISTIC - 1990

REGION	# OF ACCOUNTS FORECAST		1980 CONSUMPTION PER ELEC HTG ACC			FORECAST SPACE HTG	SPF	% PENET.	SAVINGS IN kWhr/yr TOTAL	PER ACC HTG	RES
	HTG	RESID.	TOTAL	L&A.	H.W						
Metro	53000	438300	14046	4775	4580	3354	2.0	0.25	235478	4	1
Fraser Valley	21800	237200	17676	4775	4580	7025	2.0	0.25	191425	9	1
Central Interior	16900	111100	19762	4775	4580	8918	1.6	0.00	0	0	0
North Coast	8700	34200	20959	4775	4580	10680	2.0	0.25	116144	13	3
Southern Interior	31500	145100	17222	4775	4580	7161	2.0	1.00	1127860	36	8
Vanc. Island	91500	257100	16879	4775	4580	6062	2.0	0.50	1386620	15	5
ALL HYDRO	223400	1223000							3057530	14	3

PESSIMISTIC - 1995

REGION	# OF ACCOUNTS FORECAST		1980 CONSUMPTION PER ELEC HTG ACC			FORECAST		Z	SAVINGS IN kWhr/yr		
	HTG	RESID.	TOTAL	L&A.	H.W	SPACE HTG	SPF	PENET.	TOTAL	PER ACC HTG	RES
Metro	65000	472700	14046	4775	4580	3290	2.1	1.00	1120200	17	2
Fraser Valley	32000	255800	17676	4775	4580	6457	2.1	1.00	1082290	34	4
Central Interior	21000	119800	19762	4775	4580	7884	1.7	0.50	340885	16	3
North Coast	10000	36900	20959	4775	4580	10040	2.1	1.00	525893	53	14
Southern Interior	38000	156500	17222	4775	4580	6811	2.0	2.50	3235040	85	21
Vanc. Island	112000	277300	16879	4775	4580	5689	2.1	1.50	5006540	45	18
ALL HYDRO	278000	1319000							11310900	41	9

PESSIMISTIC - 2005

REGION	# OF ACCOUNTS FORECAST		1980 CONSUMPTION PER ELEC HTG ACC			FORECAST		Z	SAVINGS IN kWhr/yr		
	HTG	RESID.	TOTAL	L&A.	H.W	SPACE HTG	SPF	PENET.	TOTAL	PER ACC HTG	RES
Metro	80000	514300	14046	4775	4580	2821	2.3	2.00	2550750	32	5
Fraser Valley	43000	278300	17676	4775	4580	5800	2.3	2.00	2819400	66	10
Central Interior	29000	130300	19762	4775	4580	6444	1.9	0.75	663895	23	5
North Coast	13000	40100	20959	4775	4580	8915	2.3	2.00	1310190	101	33
Southern Interior	45000	170200	17222	4775	4580	6264	2.2	5.00	7687810	171	45
Vanc. Island	140000	301800	16879	4775	4580	4998	2.3	3.00	11863800	85	39
ALL HYDRO	350000	1435000							26895800	77	19

ENERGY SAVINGS FORECAST WITH INCREASED USE OF HEAT PUMPS

OPTIMISTIC - 1985

REGION	# OF ACCOUNTS FORECAST		1980 CONSUMPTION PER ELEC HTG ACC			FORECAST		Z	SAVINGS IN kWhr/yr		
	HTG	RESID.	TOTAL	L&A.	H.W	SPACE HTG	SPF	PENET.	TOTAL	PER ACC HTG	RES
Metro	35400	381100	14046	4775	4580	4053	2.1	0.25	187898	5	0
Fraser Valley	16000	194200	17676	4775	4580	7548	2.1	0.25	158140	10	1
Central Interior	12100	90900	19762	4775	4580	9777	1.7	0.00	0	0	0
North Coast	6900	29000	20959	4775	4580	11243	2.1	0.25	101592	15	4
Southern Interior	24500	120900	17222	4775	4580	7500	2.0	2.00	1837520	75	15
Vanc. Island	71300	216900	16879	4775	4580	6508	2.1	1.00	2430480	34	11
ALL HYDRO	166200	1033000							4715640	28	5

OPTIMISTIC - 1990

REGION	# OF ACCOUNTS FORECAST		1980 CONSUMPTION PER ELEC HTG ACC			FORECAST		Z	SAVINGS IN kWhr/yr		
	HTG	RESID.	TOTAL	L&A.	H.W	SPACE HTG	SPF	PENET.	TOTAL	PER ACC HTG	RES
Metro	53000	438300	14046	4775	4580	3554	2.2	0.75	770656	15	2
Fraser Valley	21800	237200	17676	4775	4580	7025	2.2	0.75	626481	29	3
Central Interior	16900	111100	19762	4775	4580	8918	1.8	0.50	334935	20	3
North Coast	8700	34200	20959	4775	4580	10680	2.2	0.75	380107	44	11
Southern Interior	31500	145100	17222	4775	4580	7161	2.1	3.00	3544710	113	24
Vanc. Island	91500	257100	16879	4775	4580	6062	2.2	2.00	6050690	66	24
ALL HYDRO	223400	1223000							11707600	52	10

OPTIMISTIC - 1995

REGION	# OF ACCOUNTS FORECAST		1980 CONSUMPTION PER ELEC HTG ACC			FORECAST		Z	SAVINGS IN kWhr/yr		
	HTG	RESID.	TOTAL	L&A.	H.W	SPACE HTG	SPF	PENET.	TOTAL	PER ACC HTG	RES
Metro	65000	472700	14046	4775	4580	3290	2.4	2.50	3118750	48	7
Fraser Valley	32000	255800	17676	4775	4580	6457	2.4	2.50	3013200	94	12
Central Interior	21000	119800	19762	4775	4580	7884	2.0	0.75	620897	30	5
North Coast	10000	36900	20959	4775	4580	10040	2.4	2.50	1464130	146	40
Southern Interior	38000	156500	17222	4775	4580	6811	2.3	6.00	8776800	231	56
Vanc. Island	112000	277300	16879	4775	4580	5689	2.4	5.00	18584900	166	67
ALL HYDRO	278000	1319000							35578700	128	27

OPTIMISTIC - 2005

REGION	# OF ACCOUNTS FORECAST		1980 CONSUMPTION PER ELEC HTG ACC			FORECAST		Z	SAVINGS IN kWhr/yr		
	HTG	RESID.	TOTAL	L&A.	H.W	SPACE HTG	SPF	PENET.	TOTAL	PER ACC HTG	RES
Metro	80000	514300	14046	4775	4580	2821	2.7	5.00	7103580	89	14
Fraser Valley	43000	278300	17676	4775	4580	5800	2.7	5.00	7851740	183	28
Central Interior	29000	130300	19762	4775	4580	6444	2.3	1.50	1584370	55	12
North Coast	13000	40100	20959	4775	4580	8915	2.7	5.00	3648750	281	91
Southern Interior	45000	170200	17222	4775	4580	6264	2.5	15.00	25369800	564	149
Vanc. Island	140000	301800	16879	4775	4580	4998	2.7	13.00	57268300	409	190
ALL HYDRO	350000	1435000							102827000	294	72